Space Nutrition

Scott M. Smith
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Lisa Neasbitt
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Illustrations by Marco Zambetti

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Preface

The "Adopt-a-Classroom" project was started as a way to help bring upper elementary and intermediate school students closer to space research, and specifically to the Calcium Kinetics experiment that flew on Space Shuttle mission STS-107. The Space Nutrition newsletter was the focus of this project, and the first issue of Volume 1 was released in October of 2001. The newsletter was created by scientists in NASA's Nutritional Biochemistry Laboratory. All of the newsletters are available online at: http://www.nasa.gov/centers/johnson/slsd/about/divisions/hacd/education/kids-zone.html.

The first issue of Volume 2 of the newsletter was released in September 2002 and highlighted the importance of safety at NASA, in the context of a delay in the STS-107 mission. The monthly newsletters reflected our building excitement as the mission drew nearer. The January 2003 issue was sent out the week of the launch.

The tragic loss of Columbia and her crew on February 1, 2003, was devastating for those involved with the crew and the mission, as well as for the nation. We soon realized the impact that the newsletters had on the students and teachers that we interacted with. The cards and letters we received from students, many of which were described in the issues released following the tragedy, were a source of strength for us here at NASA. We also worked to provide the students a sense of understanding of the tragedy, of where we were and how we were doing, and a broader vision for the future of space flight and the Space Shuttle. The bonds created, or perhaps just realized, in the wake of the loss of Columbia, have in part provided us the strength to carry on with this dream of space exploration. The final issues of Volume 2 reveal the initial forward movement.

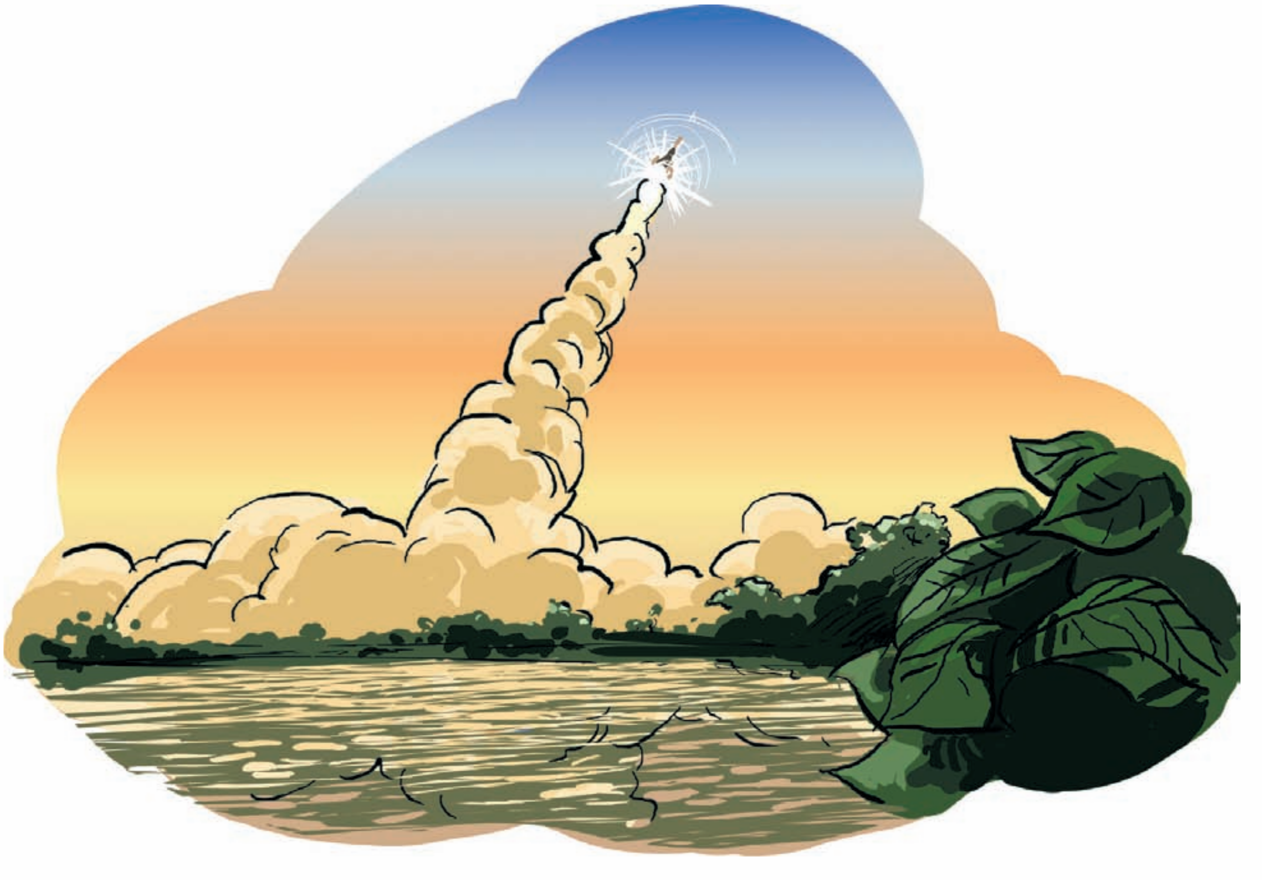
In the years following those first two, the newsletter evolved to provide a monthly update of ongoing research activities related to nutrition and space, including flight and ground experiments. Many topics were covered, from general summaries of experiments and other Nutritional Biochemistry Laboratory activities to information about individual nutrients. Among the several aims of the newsletters, one aim was to provide a sense of the teamwork it takes for an experiment to succeed, the time required for planning and preparation, and the care and dedication needed to fly an experiment on the Space Shuttle or International Space Station. We also sought to provide information about nutrition, and how it affects life on Earth as well as during space flight. Highlighting the scientific research process and the amazing work going on in orbit, on both the Space Shuttle and the International Space Station, was also a key objective. In general, we wanted to provide a sense of participation for the students, to help them understand and appreciate how science might affect their lives and how they may someday wish to pursue goals similar to those of us here at NASA.

For multiple reasons, the monthly newsletter production stopped in September of 2007. This book represents the spirit of the newsletter, formatted into a book with sections that describe the exciting world of doing nutrition research in space—Understanding Space Flight, Doing Nutrition Research in Space, and Space Flight Nutrition.

We hope that this book will engage and excite students, teachers, and parents about the work going on in our tiny corner of NASA. The final writing of this book was completed in 2011, the 50th anniversary of human space flight, the 50th anniversary of the Johnson Space Center, the 30th anniversary of the first Space Shuttle mission, and the year of the final Space Shuttle mission. We have been honored, awed, and humbled to have the opportunity to work with the space program over the years, in some small way. We hope that between the initial newsletters and this book, that readers will have the opportunity to share in our journey of scientific and space exploration.

SECTION ONE

Understanding Space Flight



Adapting to Space Flight

When flying in space, the human body feels that it is in an environment very different from the ground. You spend your whole life on the ground with gravity—and in space, all of a sudden that changes. The body does a great job of quickly realizing this, and it starts to change to get used to this new world—a process we call adaptation. Adaptation to space flight affects almost every part of the body in one way or another: heart, muscles, bones, stomach, blood, even your inner ear (the part that helps you keep your balance). This can make the first few days of space flight very rough, sort of like living on a roller coaster!

Most of these changes don't have a negative effect while you are in space, but some can have large effects when you land on Earth again. For example, your body needs less blood while you are weightless, probably because it is easier to get blood (and oxygen) to all parts of the body without gravity. This adaptation takes a week or two. During that time your body lowers the number of blood cells and

What does it mean to "orbit"?
An orbit is the path an object takes around another object. We say that the Shuttle and International Space Station orbit around the Earth, and they do this once every 90 minutes.

the amount of fluid circulating in your blood vessels. Some of the fluid (that is, water) is shifted out of the blood vessels and into other areas of the body (like into cells) or out of the body (in urine). This works fine in space, but when you come back to Earth, your body won't have enough blood, so we need to be careful that the astronauts don't faint on their return to Earth's gravity! To help prevent problems, about 45 minutes before returning to Earth, the astronauts drink a liter of salty solution to help them during and soon after landing.

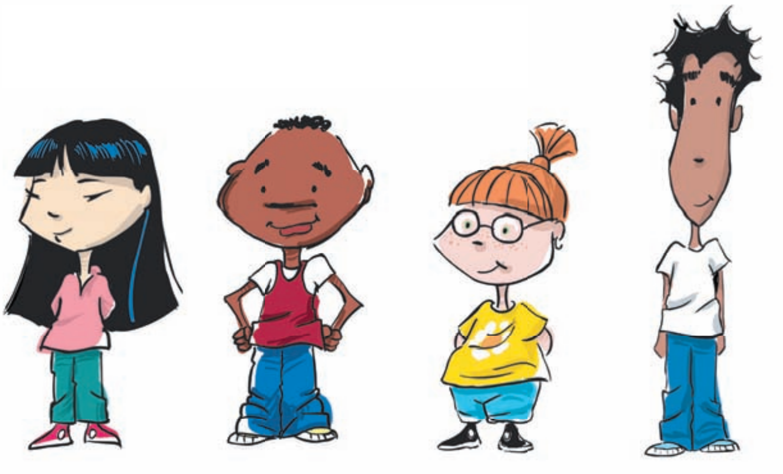
The muscles also weaken during space flight. This is called "muscle atrophy." We're still working to understand the details of why this happens, but it seems that because the body doesn't use muscles the same way in weightlessness as on Earth, the unused muscles will weaken. Although this doesn't matter while an astronaut is orbiting the Earth, it is very important for walking around after landing. This is harder on crews on the International Space Station (ISS), who stay in space for months. The longer the flight, the weaker the muscles get. Astronauts exercise hard every day to try to avoid these changes.

Wheels Stop
Adjusting to Earth's gravity after a space mission can be very hard, similar to getting off a roller coaster. One astronaut said that "gravity was no friend of mine" soon after landing.

Understanding and preventing the negative changes that occur during space flight is an important job. Researchers at the Nutritional Biochemistry Laboratory at NASA's Johnson Space Center in Houston spend a lot of time on this, because good nutrition may be one way to help keep astronauts healthy during space flight. In the next chapters, we will tell you all about the work going on in the Nutritional Biochemistry Laboratory, and also what good nutrition means to you!

Space History (and Present)

The Space Nutrition Team – Lin, Tim, Thea, and Diego – are here to guide us through the history of space flight, and through the many historical aspects of space nutrition. This team was created and developed with the help and love of our graphic artist.



Did you know?

Russian cosmonaut Yuri Gagarin (depicted here) was the first human in space. He launche from Russia on April 12, 1961. Although he was in space for only a short time (108 minutes, to be exact!), this was a big step that paved the way for the future space programs.

Mercury

Mercury was the United States' first space program that sent humans to space. Mercury astronauts were launched into space on either a Redstone or Atlas rocket, depending on how far they traveled.

Alan Shepard was the first American in space. He took his first trip to space less than 1 month after Yuri Gagarin's flight, and it lasted 15 minutes and 28 seconds. That first flight was a suborbital flight, meaning that it did not orbit the Earth.

★★★★★★★★★★

The Mercury program ended with Astronaut Gordon Cooper completing 22 orbits around the Earth and staying in space for a whole day (a little over 34 h).

★★★★★★★★★★

Did you know?
The first orbital flight, part of Project Mercury, was flown by John Glenn. His spacecraft, the Friendship 7, was launched on an Atlas 6 rocket. He orbited the Earth 3 times for a total of almost 5 hours in space. John Glenn was also NASA's first astronaut to eat anything in space. Foods enjoyed by Mercury crew members included bite-sized cubes, freeze-dried powders, and semi-liquids in aluminum tubes that looked like toothpaste tubes.

Gemini

The Gemini program, Project Gemini, was created to bring NASA one step closer to going to the moon. It included the first 2-person missions, and the first space walk by an American!

Foods used in Project Gemini were a little better than the original items developed for Project Mercury. They included foods like shrimp cocktail, chicken and vegetables, pudding, and apple sauce.

Apollo

In 1961, when the U.S. had had about 15 minutes of space flight experience, President Kennedy challenged us to get to the moon by the end of the decade. With tremendous teamwork and an outstanding effort, in 1969 the Apollo 11 crew landed on the moon. At 4:18 p.m. EDT on July 20, 1969, Neil Armstrong radioed the first words from the moon: “Houston, Tranquility Base here.

The Eagle has landed." Just under 7 hours later, he took the first steps out of the lunar module and proclaimed "That's one small step for man, one giant leap for mankind."

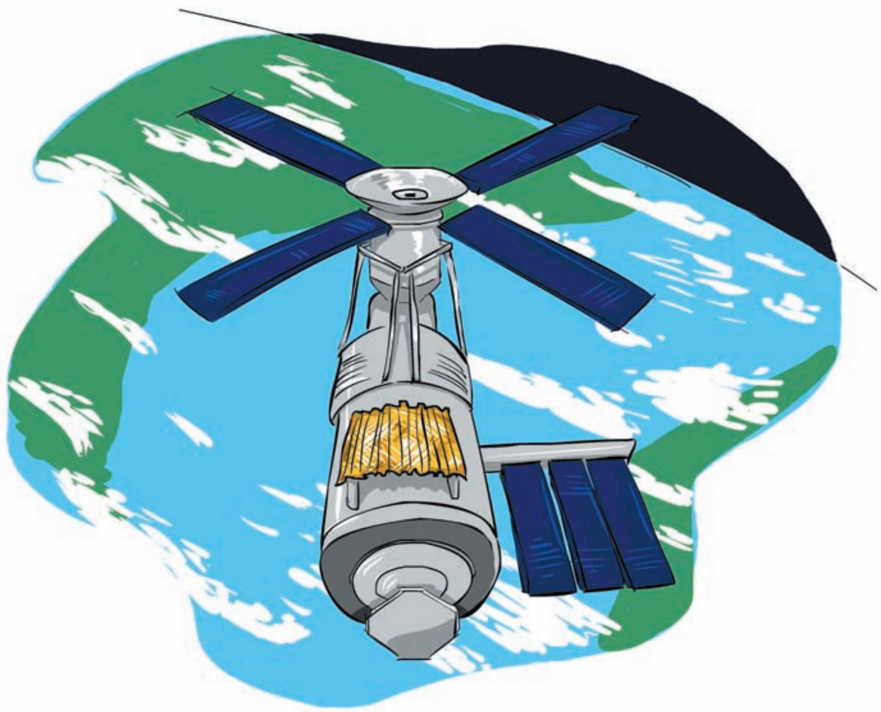
This figure depicts a very famous photograph. Neil Armstrong was not only the first person to step onto the moon, he was also the first lunar photographer, taking this picture of Buzz Aldrin, the second person to step onto the moon.

The Apollo astronauts were the first to have hot water in space, so the variety of space foods increased even more. On Christmas Day, 1968, the Apollo 8 crew ate a package of turkey and gravy and ate with spoons. The Apollo crews enjoyed bread slices with sandwich spreads and cheddar cheese spreads, and even frankfurters. Fruit juices were also added to the menu.

Skylab

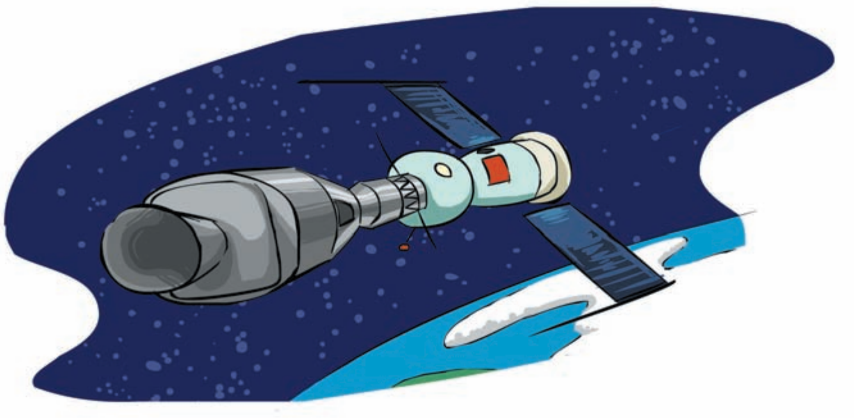
The first space station built by the U.S. was Skylab, depicted in the figure below. The goals of the Skylab program were to prove that humans could live in space for long periods of time, and to perform scientific experiments. Astronauts on Skylab used specially made equipment to keep an eye on, and better understand, what happens to the body when it is exposed to weightlessness for a long time. They also measured radiation from the sun and observed the Earth from space.

Skylab had one of the best space food systems. One area on the station had space for a dining room and table. A refrigerator and freezer were also available for storing food, and therefore the menu could be more extensive. The Skylab astronauts could choose from 72 different food items, including steak and vanilla ice cream.



Apollo-Soyuz Test Project

The Apollo-Soyuz program was the first joint space program of the U.S. and Russia, and resulted in one mission. The mission was 9 days (July 15-24, 1975), but a great deal of planning went into those 9 days.



During the Apollo-Soyuz mission, a U.S. Apollo spacecraft launched from the U.S. and docked (that is, connected) with a Russian Soyuz spacecraft that had launched from Russia. Engineers had to design a special docking module that would fit onto both spacecrafts. The figure above depicts this mission, with the Apollo capsule on the left and the Soyuz capsule on the right. Photos of this event are unavailable, as there was no third spaceship to take the picture from!

The Apollo-Soyuz docking module was basically a 3-meter-long (about 10 feet) tunnel, and it served as an airlock between the two vehicles. This was required because the interiors of the two vehicles had different atmospheres, with different pressures and different mixtures of gases, and the airlock allowed the 2 crews to meet in space without a sudden pressure change.

The Apollo and Soyuz crews shared meals and performed experiments together. This program was a big success overall, and paved the way for the future when these nations would work together again in space.

Space Shuttle

The Space Shuttle was the world's first reusable spacecraft. Shuttle missions were 5 to 16 days long, and had as many as 8 crew members. The part of the Space Shuttle that had wings was called the "orbiter." Inside the orbiter was the crew compartment (that is, the place where the crew members worked, ate, and slept). The crew compartment had 2 levels: the flight deck and the mid-deck (or middle deck). The flight deck was "upstairs," and was where the commander and pilot (and 2 other astronauts) sat and controlled the flight, and could see out the windows. The mid-deck was "downstairs," and was where most experiments were conducted, where the "kitchen" was, and where the bathroom was.

Did you know?
The first Space Shuttle mission, STS-1, launched April 12, 1981. The longest Shuttle mission ever was 17.5 days on STS-80 in 1996. STS stands for Space Transportation System.

Shuttle astronauts prepared their food in the galley on the orbiter's mid-deck. The galley was a kitchen area, and had a water dispenser that could deliver warm or cool water. It also had a convection oven to warm foods. This oven was hot enough to warm foods, but it wouldn't be hot enough to bake foods - like cookies!

Astronauts on Shuttle flights had a 7-day menu cycle, which meant that the foods they ate were the same every 7th day.

The Shuttle-Mir Program was a series of space missions from 1994 to 1998. It consisted of 11 Space Shuttle flights to the Russian space station Mir. The goals of this program were to learn how to work with international partners, gain experience in successfully living in space for many months, and conduct scientific experiments related to biology, weightlessness (also called “microgravity”), and Earth’s environment.

This is what some of the foods look like that we currently use. Many of the foods are packaged in a special container that can be used as a bowl after water is added to rehydrate the food. All of the foods are wrapped in special materials to make the foods last longer. Also, notice that the straws have a special one-way valve to prevent liquid from escaping when they are not in use.

Sergei Krikalev (depicted below) was the first Russian cosmonaut to fly on the Space Shuttle, in 1994. This mission was called STS-60, and the Commander for this flight was Charlie Bolden. Commander Bolden participated in experiments to study fluid balance in the body during flight. He went on to be appointed by President Obama to become the NASA Administrator in 2009!

The crew members aboard Mir had their choice of American or Russian food. Astronaut Andy Thomas described the food this way: "The Russian foods were really good. The Russian soups were just outstanding." He went on to say "It was really a good selection of food, actually. The food is largely canned food and rehydratable foods, much like you might use on a camping trip or something like that, and I had more than enough to eat."

International Space Station

The International Space Station (ISS) is a giant environment for living and working that orbits the Earth once every 90 minutes. The ISS was built in sections called "modules" that were taken to space either in the Space Shuttles or on Russian launch vehicles. These huge modules, and other parts, were attached to the ISS by astronauts during space walks. The first module was launched in 1998, and construction of the ISS is nearly complete in 2011. Even though the ISS is traveling almost 200 miles above the Earth at 17,500 miles per hour, on a good night you can see it with just your eyes! Check out NASA's Web sites for when the ISS might pass over your head!

Did you know?
Since November 2000, astronaut and cosmonaut teams have lived on the ISS continuously. That really is quite amazing!

Exploring space is a huge challenge. It requires teamwork from countries around the world. Just as the United States has NASA, other countries have their own space organizations. The international space organizations represent 16 countries and are NASA's international partners (IPs). For the ISS, the IPs are the Canadian Space Agency, the European Space Agency, the Japanese Aerospace Exploration Agency, the Russian Federal Space Agency, and the United States' space agency—NASA. All of the partners work together to accomplish one task: learning more about space.

The ISS crews are international as well. Six crew members live on the ISS, and they come from the U.S., Russia, Canada, Japan, and Europe. The U.S. and its IPs make new foods to try to increase the variety of foods available to crew members.

★★★★★★★★★★

All of the parts of the ISS were built on the ground by NASA and its international partners. For example, the Canadian Space Agency built a robotic arm; the European Space Agency built the Columbus Laboratory module; the Japanese Aerospace Exploration Agency built a Japanese Experiment Module that is composed of three segments and is known as Kibo, which means "hope" in Japanese. The Russian Federal Space Agency built the Functional Cargo Block, FGB for short, known as Zarya (the Russian word for sunrise), and NASA built the lab module called Destiny. These huge pieces were built in different places, at different times. They were never near each other until they were attached in orbit!

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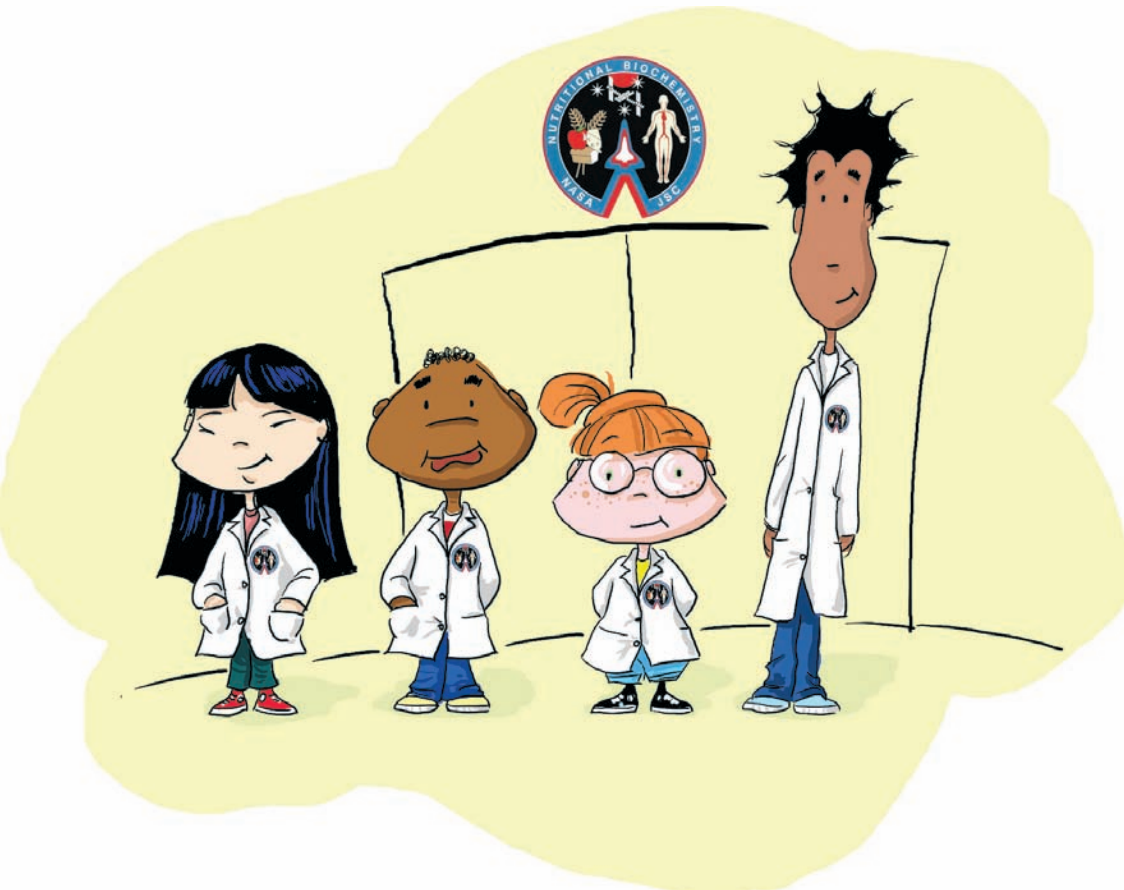
SECTION TWO

Nutrition – What is it, what does it have to do with astronauts, and what does it have to do with me?



In this Section, Lin, Tim, Thea, and Diego—the Space Nutrition Team—help us understand more about the world of nutrition research.

Biochemistry is a fancy word for studying how living organisms work—all the way down to the chemicals in the cells that make up the body. Nutritional biochemistry is the study of how nutrients in food affect how our bodies work. Every cell in your body requires many different vitamins and minerals as well as energy to keep you alive and healthy.

Did you know?
There are special rules for creating new space foods:

-Minimize crumbs
-Minimize packaging and trash volume
-Minimize the weight of the food

In one sentence, the job of the Nutritional Biochemistry Laboratory is to figure out how much of each nutrient (the calories, protein, vitamins, calcium, other minerals…you name it) the body needs during space flight—in other words, the nutrient requirements for space flight. To figure out what the requirements are, the people in our laboratory do research. As we find out new information about these nutrient requirements by doing research, the information is handed over to specialists in NASA's Space Food Systems Laboratory. They have the tough job of developing foods and menus that will not only meet the nutrition requirements, but also obey the many other special rules that are made for space foods. These rules are discussed in more detail in the Space Food section ahead.

Research - Nutrition or Otherwise

So what is meant by the word "research"? To conduct research, scientists do experiments to learn about things in the world. Just as you do in your science fair experiments, researchers learn new things by asking questions, testing theories or hypotheses, observing how things happen, and making conclusions about things they learned. Once you know and understand how something works, you can predict how it will behave in the future. This process is called the scientific method. You use the scientific method if you've ever entered a science fair competition, and it is exactly what we at NASA use every time we do an experiment on the ground or in space. In the next few paragraphs, we'll walk you through the scientific method and we will also describe how we used this process for one of our experiments.

An experiment is born - Observation

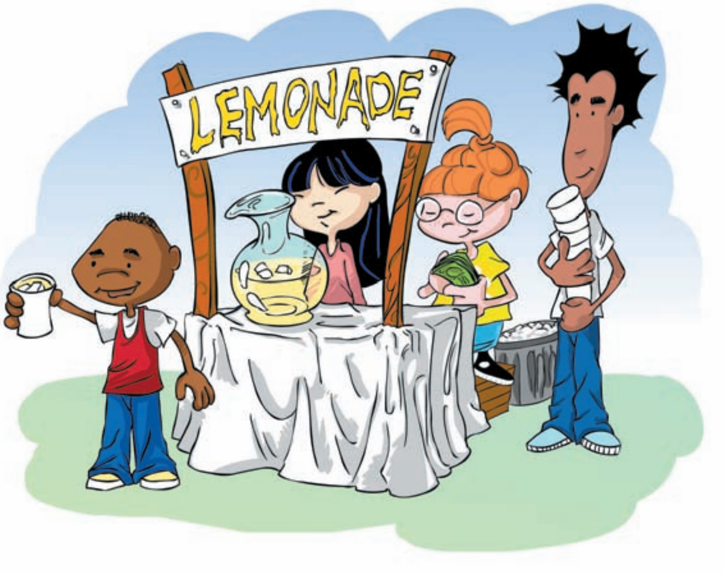
Observation is the first step of the scientific method. We propose experiments when we want to answer questions about observations we have made. The answers that come from doing experiments are more reliable answers than answers that are only an estimate, or a guess. Science is based on answering questions with

Example of an observation...
Summertime is hot! When it is hot, people like to drink ice-cold lemonade more often.

evidence or confirmed information. The more evidence you have, the better your conclusions will be.

What's a Hypothesis?

A hypothesis is an “educated” guess. It could be a guess based on a previous experience or a similar situation. It’s more reliable than answering a question by saying “because I think so.”

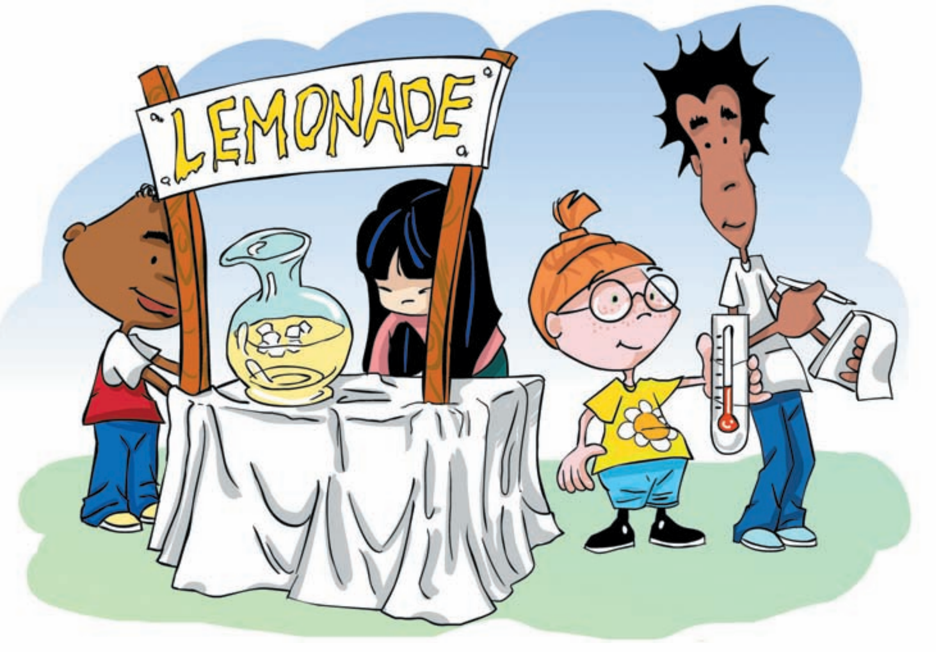


Let's say you had a lemonade stand and you noticed that you had a lot more sales one week than you did the next week. You would then try to think of differences between the weeks that could explain the rise in sales, and there would likely be many. Maybe you would decide that the outside temperature made a difference and people are more thirsty when it is warmer. The next step is to test your hypothesis that warmer temperatures influence lemonade sales at your stand.

Experiment

The experiment is the next step of the scientific method. An experiment is the testing of your hypothesis in a controlled manner. This means that you have a well-defined process or procedure for each step of your experiment, so that someone else could repeat it. There are several ways to perform each experiment. When scientists propose to do an experiment, their proposal is reviewed by other scientists who are experts in that area. These reviewers can suggest ways for the scientists who proposed the experiment to make their experiment better. The best experiments are well planned and reviewed many times by many people and groups. This is just one step in the process of getting an experiment from an idea to space and back!

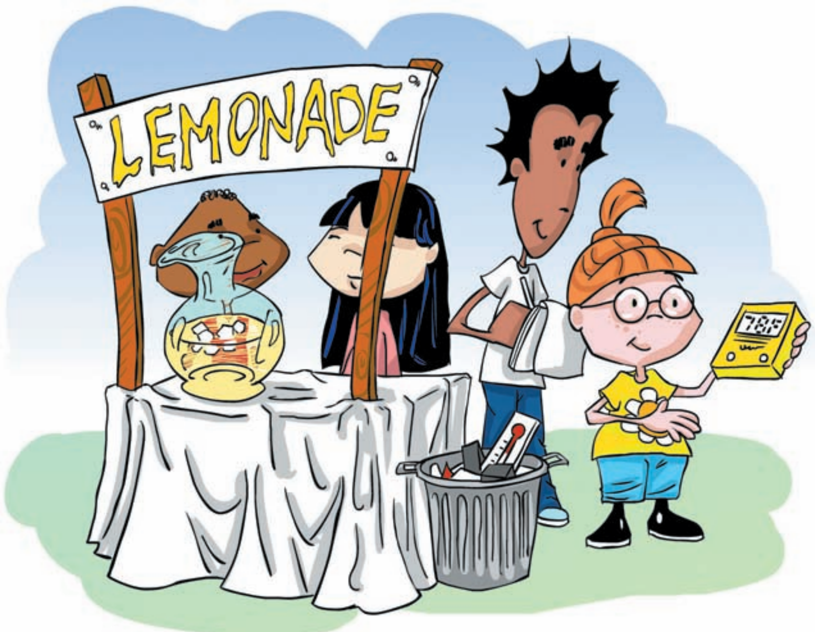
To test your hypothesis that temperature affects your sales, you could record (write down or enter into a computer) the outside temperature along with the number of sales each day. If you had an indoor lemonade stand, you could adjust the room temperature to be higher one week and lower the next week.



Data collection and Analysis of results

At the end of your experiment, you always want to have some sort of measurable outcome. Collecting good information from your experiment is important. Using tools that have been calibrated, or checked to make sure they are accurate, is important.

In the lemonade stand experiment, if you used a thermometer that was broken or didn't work properly, then your results and conclusions would not be accurate.



When you finish collecting information, or data, then you will want to determine what it all means. This process is called analysis. You could make a graph and plot daily temperature versus number of drinks sold, which would be an easy way for someone to quickly look at your data and interpret what, if anything, your experiment tells you—the conclusion of your experiment.

Conclusions

Drawing conclusions and reporting results of experiments is very important. Even if your experiment doesn't give you data that tells you that your hypothesis is correct, the information is still valuable and others can learn from it. Writing a report of the whole process—observations, hypothesis, details of the experiment, showing the data you collected, and putting it all together in a conclusion—is something scientists do regularly so they can let others know what they are doing. It's exactly what you would do for a science fair. Scientists publish their reports in scientific journals. If the project is related to studying bones, then a bone journal would be appropriate. If it's related to leaves, then a plant journal would be appropriate. There are hundreds of scientific journals, and each has specific areas of interest. The Nutritional Biochemistry Laboratory does research in several different areas and has published reports of its research in many journals, for example the *Journal of Nutrition* and the *Journal of Bone and Mineral Research.*

Space Nutrition Research

Now, let's walk through the first steps of an experiment we have done in NASA's Nutritional Biochemistry Laboratory.

Our Observation

To evaluate a person's health with respect to a specific nutrient, doctors or scientists will often collect blood or urine samples. To evaluate a person's vitamin D status, we collect blood. We observed lower concentrations of certain vitamins, including vitamin D, in blood samples collected from astronauts after space flight than in blood samples collected from the same astronauts before flight. As you will learn later in this book, vitamins are important and they can do specific jobs in our body. If we don't have enough of any one vitamin, that is, we are deficient in it, we can become very sick. The symptoms of the sickness will depend on which vitamin is missing. In general, a balanced diet can help prevent deficiencies. That means eating a variety of foods and food types, and even a variety of colors.

Did you know?
"Deficient" means that you are missing something that is necessary.

Our Hypothesis

We didn't know the exact reason why the astronauts' vitamin D levels were lower after flight, but we hypothesized that the crew members were simply not getting enough vitamin D from their food or their environment. Our hypothesis was based on several pieces of information, so it wasn't just a random guess but rather an educated guess. We knew that space foods are low in vitamin D. Vitamin D is not present in many foods naturally, except for fish such as salmon, and there are not many space food items that contain salmon or vitamin D. Also, vitamin D is a unique vitamin because your body can make it when you are exposed to the sun. Did you know that children who do not get enough vitamin D, either from exposure to sunlight or from their food, can have bowed legs or rickets because vitamin D is important for bone health? Getting some (but not too much!) sunlight exposure is important, as is consuming foods that contain vitamin D—like fish, milk, yogurt, and fortified cereals.

Because astronauts are shielded from the sun by their space suits and the International Space Station itself, their bodies cannot make any vitamin D while they are in space. So, because their bodies cannot make vitamin D, the space food system is low in vitamin D, and their vitamin D status decreases after flight, we made an educated guess that the amount of vitamin D that they are currently getting in space is not enough to meet their needs. We then performed several experiments to test pills (supplements) containing different doses, or amounts, of vitamin D. You will learn more about these experiments in the vitamin D chapter later in the book.

Space food

None of the U.S. space foods used today are served in tubes as they were on the early flights, like Apollo and Gemini missions. Space foods on the International Space Station are either rehydratable, thermostabilized, or in natural form. A rehydratable food is one that is dehydrated, meaning all of the water has been taken out. You might be familiar with some of these, like packets of hot cocoa mix or dried noodle soups. To eat one of these items, you must rehydrate it, meaning you must add the water back. Thermostabilized foods are heated to high temperatures and packaged in cans or closed pouches. Examples of thermostabilized foods are canned ravioli and soups. We also use some foods in their natural form, that is, just like they are in nature (or at the grocery store). A food in its natural form is in a vacuum-sealed package, meaning all of the air has been removed so that it stays fresh for a long time. These foods include nuts and dried fruit.

The ISS crew members eat international foods, as the crew members are from many different countries. Right now, half of the space food items on board the ISS are American foods and half are Russian foods. Japanese, European, and Canadian food items are available also. The astronauts and cosmonauts have more than 300 food items to choose from.

Did you know?
"Dehydrated" means that the water has been removed and the solid matter has been left behind.

"Thermostabilized" means that foods have been heated a certain way to destroy bacteria in the food that could make it spoil.

Preparing food to eat in weightlessness is a challenge. Crumbs are not allowed, as they can float around the cabin and could float into someone's eye (or nose) or into instruments, or clog air vents. Also, the food must not float away while an astronaut is trying to eat it, so packages and foods are designed to make this less of a problem in space. Another challenge for food system developers is trash. Wrappers and empty packages must be compressible to minimize the amount of trash on the spacecraft. The garbage truck doesn't stop by the International Space Station, and there are very few opportunities to get trash off the vehicle. In fact, trash is disposed of only when space vehicles such as the Space Shuttle, the Soyuz capsules, and other cargo vehicles visit the ISS and then depart. This happens about once a month, and even these vehicles have limited amounts of space available, so trash must be as compact as possible. These are just a few of the challenges of developing space foods. The NASA Space Food Team does a great job of meeting these challenges, and of developing foods that the astronauts will like during their space missions.

Did you know?
Some space foods are irradiated. These foods are packaged and then exposed to a source of radiation that kills any mold or bacteria on the food, allowing it to be safe to eat for a long time.

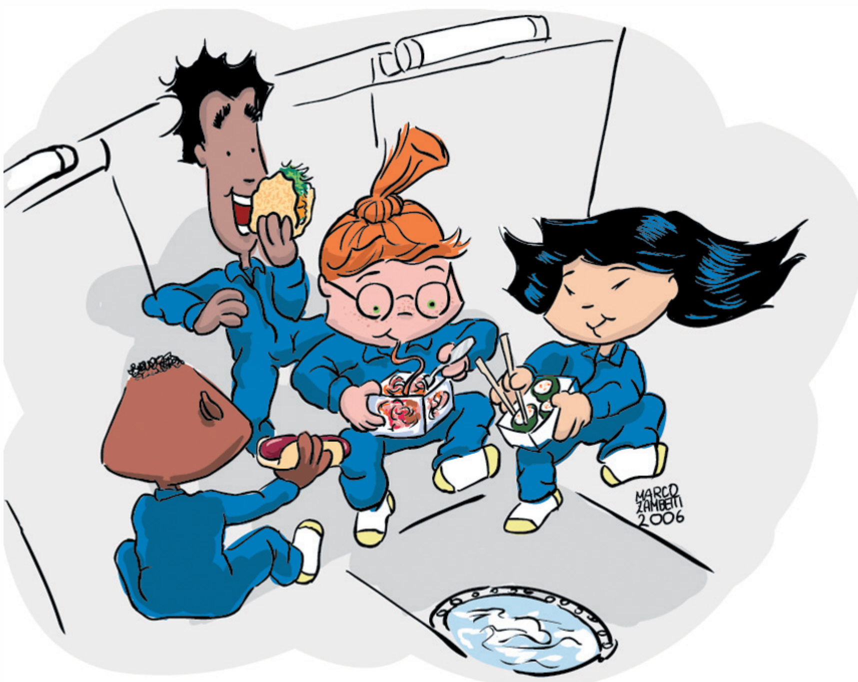
Food storage is a big issue for space travelers. Until recently, the ISS had no freezers or refrigerators for food, so the food has had to be "shelf stable" and not likely to spoil for at least 6 to 12 months. Food for a Mars mission will need to be stable for up to 5 years. Recently, a small refrigerator-freezer known as MERLIN (Microgravity Experiment Research Locker/Incubator) was flown to the ISS. It can be used to store a small amount of fresh food and drinks. This is especially helpful for drinks, which up to now have been pretty much room temperature. Nothing beats a cold glass of juice!

Taste and texture—how the food feels in your mouth—are very important for space travelers. Many taste tests are conducted on Earth when new foods are being developed for space travelers. When adapting to space flight, some astronauts have reported that their tastes changed, and that in space they tended to like spicier foods. One of the reasons for this is related to congestion that astronauts sometimes have, similar to when you have a cold and your nose is stuffy. Most of the ISS crew members say that this is troublesome only in the early days of flight, and that after a week or two, foods taste great.

Before each mission, astronauts select their favorite foods from the available flight foods, and they taste the foods they have selected to make sure that they really do like them. The most popular space food is shrimp cocktail, in part because of the spicy sauce!

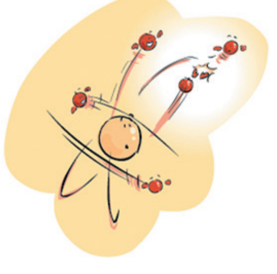
Other challenges in developing space foods are making sure that they are tasty, have good nutrient content, and can be easily prepared. Another big challenge, especially as we begin to think about sending humans to the moon and Mars, is shelf life (how long the foods will stay fresh). Even for an International Space Station flight, the foods have to be able to sit on the shelf (a shelf in the pantry, not in the refrigerator or freezer) and still be tasty for at least 9 months. It will be even longer for a Mars mission. Can you imagine going to the grocery store, filling your pantry with food—and not going back to the store for a year, or 2 or 3?

Food scientists in the Space Food Systems Laboratory at the Johnson Space Center have created another success story. They have developed special tortillas that taste good after almost a year. Tortillas in space work great for making sandwich roll-ups (a regular sandwich with two slices of bread would take three hands to make—otherwise one slice will float away!). The scientists keep these tortillas fresh with special packaging that includes an oxygen scavenger. An oxygen



scavenger is a chemical that traps oxygen, and the lack of oxygen in the packaging prevents mold from growing.

Some space foods are irradiated. These foods are packaged and then exposed to a source of radiation that kills any mold or bacteria on the food, allowing it to be safe to eat for a long time. No radiation stays on the food. This is like when you go to the doctor to get an x-ray, once the x-ray is taken, there is no radiation on you.



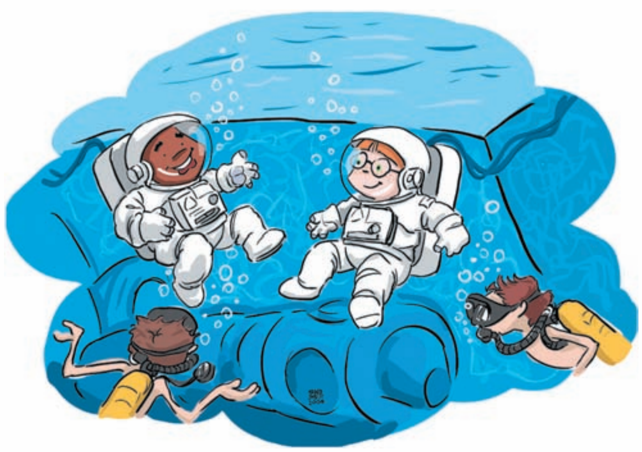
There are many types of radiation besides x-rays. One type that is found in space is cosmic radiation. The spacecraft (and astronauts) are shielded from most of the harmful cosmic radiation. This shielding prevents astronauts from getting vitamin D from sunlight as they would here on Earth. We have to take extra care to make sure astronauts get enough vitamin D from foods. Remember our vitamin D hypothesis?

Some forms of cosmic radiation do get through the spacecraft wall. In addition to being a concern for the health of the astronauts, this radiation is also a concern for the food. Radiation might affect vitamins and nutrients in the food before it is eaten, and the foods might not taste good, or might have fewer nutrients than we think. If this happens, we'll need to find ways to better shield the foods, either by packaging each item in a new material, or by making new large protective containers that could be used for many food items.

Space Walks: The Smallest Spacecraft

Space walks, or what NASA calls “extravehicular activity” (EVA), are a very important part of many space missions. When astronauts need to go outside the Space Shuttle or International Space Station, they have to put on a special suit that acts like a personal spacecraft. The EVA suit provides pure oxygen for the astronauts to breathe, and is cooled with a special suit underneath that can have cool water circulating throughout it. During an EVA, astronauts can be in these suits for up to 10 hours.

To train for doing EVAs, astronauts need a place that simulates the space environment where they can wear their EVA suits. The Neutral Buoyancy (bo-yun-see) Lab is a giant swimming pool for diving that allows astronauts to train for space missions involving space walks. Full-scale models of the International Space Station and Space Shuttle are at the bottom of the 40-ft pool, and there is even a mission control center that directs the activities of the dives. When something is buoyant, it has a tendency to float or rise when submerged in water. What does it mean to be neutrally buoyant? It means to have an equal tendency to float and to sink. When an item is neutrally buoyant, it is very easy to move the item while it is under water—much like moving an object in space.



Did you know?
There are more than 326 million trillion gallons (1 gallon = 3.79 liters) of water on Earth!

The Neutral Buoyancy Lab is 202 feet (62 meters) long, 102 feet (31 meters) wide, and 40 feet (12 meters) deep. It holds 6.2 million gallons (230 million liters) of water, and the water in the NBL is recycled every 19.6 hours. The water is kept at a temperature from 82 to 88 degrees.

Astronauts training in the Neutral Buoyancy Lab wear space suits similar to those used during space flight EVAs, and they breathe high levels of oxygen as they would on EVAs. Although we need oxygen to survive, too much oxygen can cause damage to cells in the body. We can measure the amount of damage by looking at chemicals in the blood and urine to see how much damage was done by the excess oxygen. Antioxidants are chemicals found in foods, such as vitamin C or vitamin E, that can reduce damage from oxygen. Colorful fruits and vegetables such as melons, grapes, peppers, tomatoes, and berries are rich in antioxidants.

Space Flight Research - General and Specific Experiments

Conducting experiments during space flight can be tough, especially nutritional biochemistry research. Obtaining some of the most basic measurements, even something as simple as measuring body weight, is challenging in a weightless environment. In fact, body weight is defined by Earth's gravity. But your body has the same mass whether it is on Earth, on the moon, or in a weightless environment. We measure body mass (but not body weight) during flight using very special equipment, called a Space Linear Acceleration Mass Measuring Device, or SLAMMD, as we like to call it.

Below is a depiction of one of the astronauts on the SLAMMD, which uses some basic math and science (physics) principles to determine the crew member's body mass.

Working with fluids in space is difficult as well, especially when you are trying to transfer a fluid from one container to another. Pouring things is impossible (well, everything is possible, but let's say that pouring things without a major spill is impossible). One of the main ways that we determine whether astronauts are healthy in terms of nutrition is to analyze blood and urine samples, both of which, as you know, are liquids. They are collected from astronauts before, during, and after space flight.

The techniques used for blood sample collection during space flight are actually very similar to those on the ground. A small needle is inserted into a vein, and it is connected to a vacuum tube. The blood is pulled into this tube.

Once in the tube, the blood usually needs to be processed. During processing the cellular and liquid components of the blood are separated from one another so that researchers can conduct tests on different parts of the blood.

Not all astronauts are doctors—in fact, most are not medical doctors. Astronauts are trained to do medical procedures that might be needed in space flight. One such procedure is drawing blood for the "Nutrition" experiment.

Depending on the type of blood collection tube that was used (and specifically, what was in the tube) the liquid part of blood is called either "serum" or "plasma." Most often, the blood is allowed to clot in the tube, much like when a wound forms a scab after you fall and scrape your knee. This produces serum, a straw-colored liquid that makes up a little more than half of the blood (most of the rest is red blood cells). Serum contains water, proteins, vitamins, minerals, salts, sugars, and lipids. The specific chemicals in serum provide a good indicator of whether or not our body systems are receiving proper nutrition. Scientists use a machine known as a centrifuge to separate the serum from the blood cells. A centrifuge is kind of like a carousel, only it is a smaller version that fits on a lab counter and spins much faster, typically rotating about 3000 times per minute! The centrifuge holds test tubes of blood in little compartments. After 15 to 30 minutes the centrifuge is finished spinning and the serum in each test tube is separated from the blood cells. Scientists can then use the serum to perform various tests.

In July 2006, a centrifuge was launched on a Space Shuttle to the International Space Station (ISS). Having a centrifuge there makes it possible to separate blood cells and serum in space. Astronauts can collect blood samples from each other and scientists can use these samples to see what happens to the human body in space.

The centrifuge in the ISS is about 12 inches across, relatively small compared to the largest centrifuges. In fact, NASA has one centrifuge here on Earth that is big enough to spin humans! (See the Artificial Gravity section.)

After the blood has been processed, it needs to be frozen, or else the chemicals we want to study will start to break down. The freezer in your kitchen uses gravity, and special technology had to be developed to make freezers work in space. On the ISS, we have a special freezer called a MELFI (Minus Eighty Laboratory Freezer for ISS). The lowest temperature that the freezer in your house can reach is about –20°C (–4°F). What temperature do you think the MELFI might be? Did you guess –80°C? This was our initial goal, but the freezer actually works better than that, and is usually –96°C. Obviously this freezer is very cold, which is important for keeping the chemicals in blood from breaking down.

Did you know?
Blood makes up about 10% of your body weight.

A man by the name of Antonin Prandl invented the first centrifuge to separate cream from milk.

Nutrition Research - Assessing Nutritional Status

In 2006 we started an experiment called the Nutritional Status Assessment Supplemental Medical Objective, or more simply the "Nutrition SMO," or often we just call it "Nutrition." This study was designed to evaluate ISS astronauts' nutritional status during space flight. To do this, we have the astronauts collect blood and urine samples throughout the mission. After these are brought home, we analyze the samples for chemicals that tell us about the crew members' bones, muscles, vitamins, and minerals. This type of testing is called "nutritional assessment"—we are checking, or assessing, nutrient levels in crew members during 6-month expeditions to the ISS. Knowing how nutrient status changes during these missions will help us better prepare for missions to the moon and Mars.

Thea and her friend Lin are taking a tube of blood out of the centrifuge on the ISS.

While they were in space, astronauts collected their blood several times into test tubes. The tubes were centrifuged and then frozen in the MELFI until they were returned to Earth on the Space Shuttle. For the Nutritional Status Assessment experiment, we analyzed these blood samples to examine the effects of space flight on nutrients (vitamins and minerals), bones, muscles, and other body systems.

Nutrition and Bone

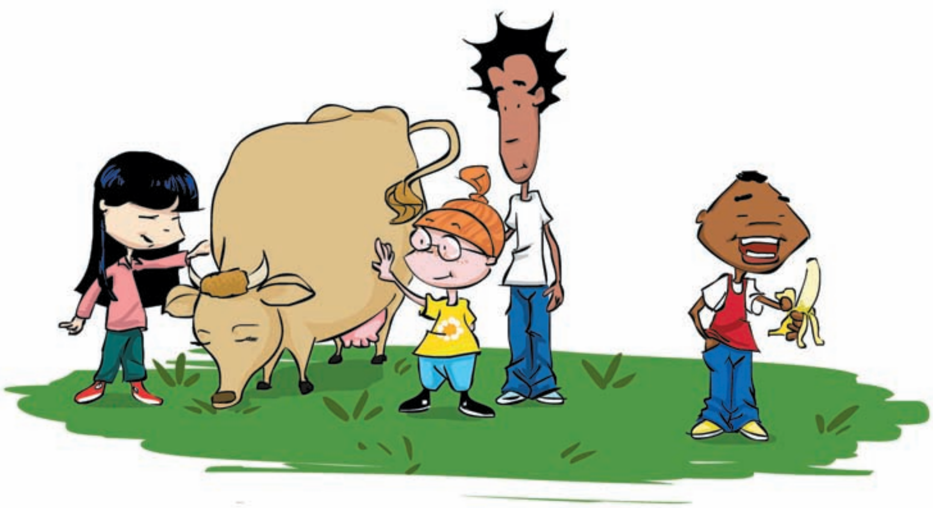
Loss of calcium from bone is a serious concern for astronauts, and nutrition provides a number of potential ways to counteract bone loss during space flight, as well as in people on Earth. In 2010, Nutritional Biochemistry Laboratory scientists started to investigate, for the first time during space flight, the ability of nutrition to lessen bone loss of astronauts. The scientists made a hypothesis that a diet with a lower ratio of animal protein to potassium will lead to decreased loss of bone mineral during flight.

This experiment, called “Pro K” (Pro is short for protein, and K is the chemical abbreviation for potassium), will help to determine the nutritional requirements and the type of food systems needed for future exploration missions. The information we get from this experiment will also help the bone health of people on Earth, because people tend to consume large amounts of animal protein and not enough fruits and vegetables.

Did you know?

Animal protein (meat and dairy foods)) tends to be rich in chemicals that produce acid in the body, while foods rich in potassium (for example, bananas) tend to have chemicals that produce base, which can neutralize the acid.

When the overall effect of the diet is acidic, this can lead to bone breakdown, and we have seen this happen in research subjects who stay in bed for a long time.



Nutrition Research - How Stable Is That Food?

In another experiment, called the "Stability" experiment, our lab investigated the effect of long-term storage on space foods. The reason we wanted to investigate this was that foods often wait a very long time (months, and even years) from the time they are prepared for flight until they are eaten. Foods become stale, or sometimes taste funny (or bad) when they are too old, and this taste is often caused by vitamins and other nutrients breaking down into other chemicals over time. If enough of a nutrient breaks down, then the food is no longer providing the nutrients we expected it to provide. It is possible that nutrient breakdown happens faster in the space flight environment than on Earth.

When you see an expiration date on a food purchased at the grocery store, it means that after that date, the nutrient content or the flavor or smell of the food is likely not good anymore.

Eating food that is past the expiration date (or older than its suggested shelf life) could even make you sick, depending on the food item.

To test this, we studied nutrient stability in foods after they had been in space for days or months at a time. We sent up 4 bags, containing different types of space foods, to space on the Space Shuttle. The foods in the bags were rich in vitamins and other nutrients that we are currently studying at NASA. Items such as salmon, almonds, and broccoli with cheese were included. One of these bags was brought back home on the same Shuttle, while the other 3 stayed on the ISS. Another bag was brought home to Earth after 11 months in space, another after 18 months, and another after 29 months (more than 2 years!). We measured vitamins and other nutrients in the foods that had been in space, and compared the measurements to data from identical foods that we stored in the laboratory for the same amount of time.

We found that storage on a spacecraft didn't cause a faster breakdown of the nutrients than storage on Earth, but that over time, many of the nutrients do break down. Actually this finding was not too surprising. As you know, many foods have expiration dates, which are placed on their packages for you to be aware of, for just this reason. What this means, though, is that as we plan exploration missions far from Earth, we need to be very sure that the foods to be eaten on those missions have the right nutrients to keep astronauts healthy, and that those nutrients will be there at the end of the mission as well as at the beginning!

To help students become aware of the shelf life, or storage stability, of food, we placed several bags filled with space food, much like the ones flown on the Space Shuttle and the ISS, in classrooms across the nation. The students and teachers then conducted tests on foods similar to those in the packs flown in space.

The results of the students' testing may be found on the Stability Space Flight Testing blog:
http://stabilityflightkitstudy.blogspot.com/

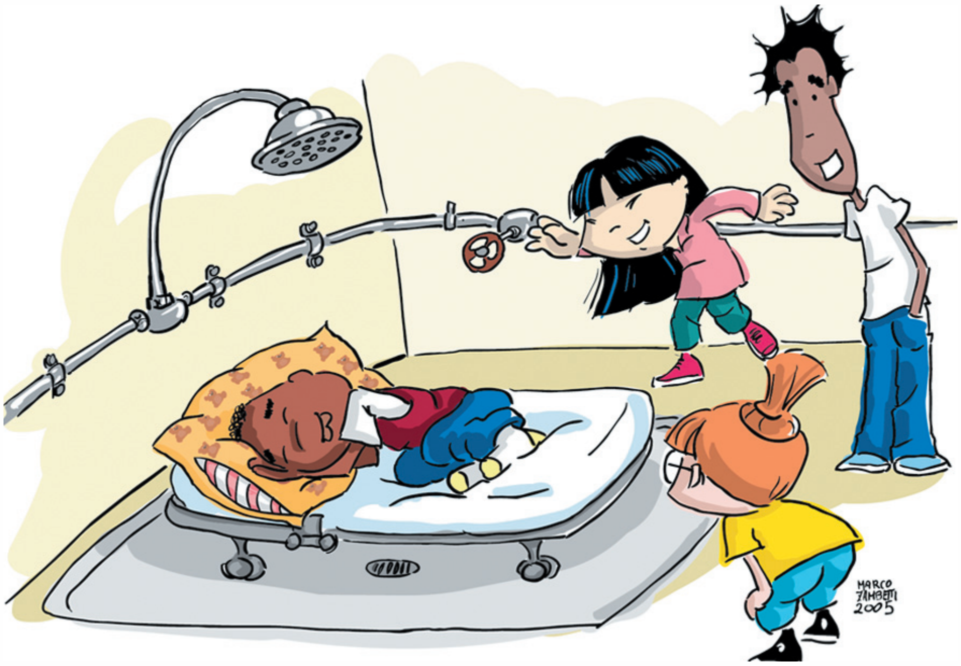
Nutrition Research in Space vs. on the Ground: What's an analog?

An "analog" is something that is similar in some ways to something else. Doing research in space is very expensive and takes a very long time because not many people can be launched into space each year. For this reason, we do some of our research here on the Earth with analogs of space flight. These are called "ground analogs." Some analogs, or models, are better than others.

Bed Rest

One of the most common ground analogs for the effects of space flight in humans is bed rest. Men or women volunteer to be research "subjects" or participants, and can spend anywhere from a few days to several months lying down in bed! During bed rest, your body doesn't use muscles and bones for their usual functions of working against gravity and helping you stand up and move around. Bed rest subjects are in bed throughout the entire study. They eat and read in bed, and even use bed pans to go to the bathroom. They can take sponge baths, or if it is available, use an invention that lets a person shower while lying down. During bed rest, subjects lose muscle and bone just as astronauts do, although the speed of loss is slower during bed rest. This is probably because these bed rest volunteers still experience gravity while they are in bed, due to the fact that they remain on the Earth. Bed rest studies help scientists study changes that occur in the human body in space, and test ways to counteract these changes.

Tim can't get up for a shower because he is a volunteer for a 90-day bed rest ground analog study at NASA. In these studies, the subjects are not allowed to get up for anything—for a full 90 days.



Did you know?
Twice in recent years the bed rest studies in Galveston, Texas, were stopped earlier than planned, and just about everything at the NASA Johnson Space Center was shut down for several days. One time was when the Houston area was evacuated for Hurricane Rita, and once again when Hurricane Ike hit the Texas coast near Galveston.

Ground analog bed rest studies require a great deal of work and many people. A lot of teamwork is involved to make sure everything gets done exactly as planned. These studies are difficult, but you can study more subjects, and collect more data, than is usually possible during real space flight.

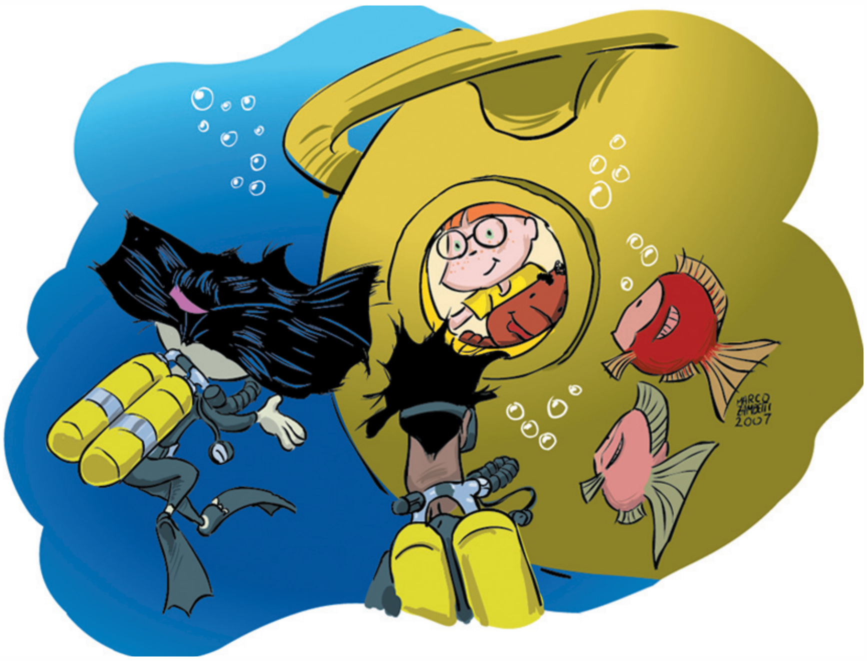
The fact that we use bed rest as a way to study changes in bone, muscle, and other body systems should show you just how important physical activity is for good health. Sitting in front of a TV or computer too long will cause your bones and muscles to start breaking down too!

Under the Sea

Did you know?
A habitat is a place or environment where people (or other creatures) can live.

Imagine your environment was in the ocean, 47 feet below the surface, for 2 weeks, and you couldn't come up for air! Several times in recent years 6 crew members (including astronauts, other scientists, and "habitat technicians") have done just that. They lived in an underwater habitat called Aquarius off the coast of Florida for a week or two. The underwater project is called NEEMO, which stands for NASA Extreme Environment Mission Operations. The crews who live and work underwater complete many scientific experiments to help us figure out what happens to their bodies, and how "aquanauts" perform in an environment similar to space flight.

Did you know?
An aquanaut is a scuba diver who can live inside and outside an underwater habitat for an extended period of time.



Diego and Lin are working outside the NEEMO habitat, and Thea and Tim are monitoring them from inside the underwater habitat. Living and working in extreme environments is a challenge that astronauts and aquanauts face.

A unique aspect of living in the habitat is that the air pressure inside the habitat is increased because it is under water, so the aquanauts actually breathe more oxygen in one breath than when they are at the surface. In a nutrition experiment, we have studied the nutritional status of the aquanauts. Specifically we have studied the effects of a high-oxygen environment on molecules in the body such as iron, protein, DNA, and fats. We can investigate these effects by measuring chemicals in the aquanauts' blood and urine to identify which molecules are affected.

When the NEEMO crews live in the underwater habitat, they do not always have direct access to medical doctors to help with medical problems that might come up. Other scientists have tested the abilities of remote-controlled robots to perform medical functions to treat patients and the ability of aquanauts to use a computer program that can talk a crew member through the proper steps to treat a medical problem. These technologies will be important for the future of NASA, when we go to the moon and Mars!

The Bottom (or Top) of the World!

Did you know?
98% of Antarctica is covered by a thick layer of ice. The average thickness of the ice sheet is 7,200 feet.

Antarctica is a good model of space flight for studying vitamin D. Vitamin D is a vitamin that your body can produce when you are exposed to sunlight.

Similar to the situation in space flight, people living in Antarctica are not exposed to any sunlight for almost 6 months at a time during their winter months (February through September).

Did you know?
No one country owns Antarctica. The Antarctic Treaty, which has been signed by 45 countries, reserves that area as a zone for the peaceful conduct of research.

Each year, more than 800 scientists from all over the world journey to different research stations in Antarctica to study volcanoes, fish that don't freeze, fern fossils, stardust, ancient bacteria, and more.

Artificial Gravity

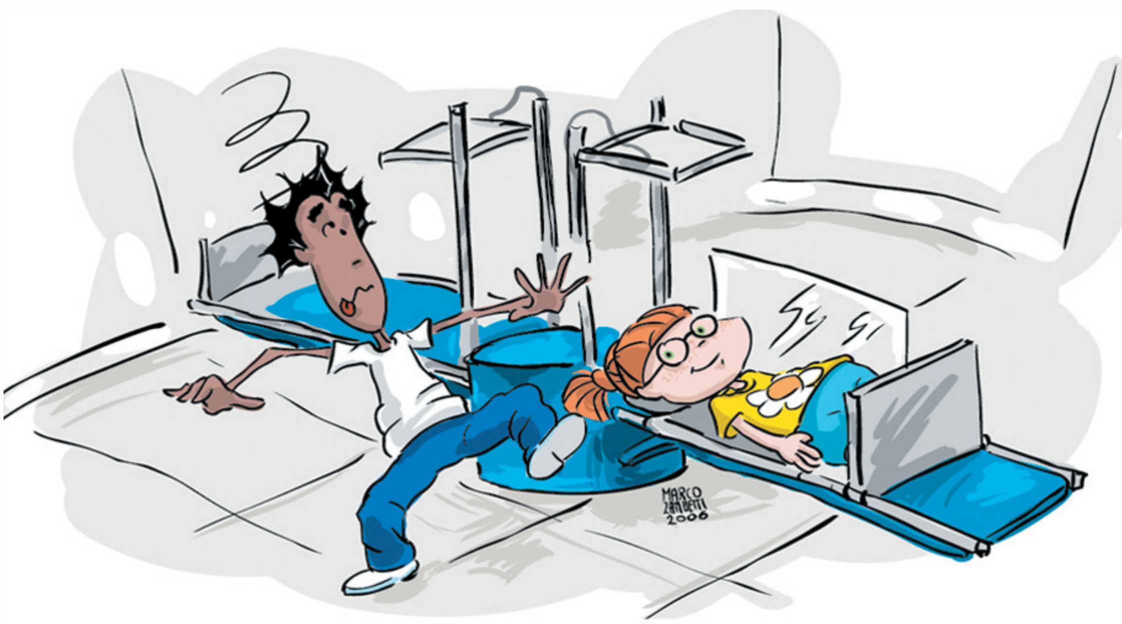
When leaving Earth's gravity, the body begins to adapt to a new environment, one where less muscle and bone is needed to help a person stand or move around, where the heart doesn't have to pump as hard to get blood to the fingers and toes, and where astronauts can move up and down with a small push-off from the spacecraft floor (or wall, or ceiling…).

To adapt to the new environment, the body changes itself. Some of these changes can be hazardous to the health of astronauts during their mission or even after they return to Earth (or land on the moon or Mars), where gravity is much greater. One possible way to minimize the effects of gravity on the body is to use "artificial gravity."

We recently completed a bed rest study in which we created artificial gravity by using a centrifuge, a device that spun people in a way that made them feel like they were standing up (even though they were lying down at the time). This device has effects much like those of amusement park rides that spin and make you feel like you are stuck to the wall. This spinning produces a force that imitates the gravitational pull of the Earth, the "force of gravity." Because the "centrifugal" force produced on the body by the centrifuge isn't the same as gravity, it is called artificial gravity.

Did you know?
Most scientific experiments have a control group and an experimental group. The experimental group is "treated" in some way—they may exercise, take a pill, or receive some other "treatment." The control group does not receive the treatment, and the data collected from them are compared with data from the experimental group. In the bed rest experiment, artificial gravity was the experimental condition. We tested whether artificial gravity protected different body systems by comparing data from the experimental group to the control group.

The bed rest experiment had people stay in bed for 21 days and split them into two groups, the control and experimental groups. Subjects in the experimental group were centrifuged for 1 hour every day, but those in the control group were not. We studied the bones, muscles, and other body systems of both groups to see if the spinning helped to reduce the negative effects of bed rest. Although this particular study showed that the centrifuge didn't help bones, it did help muscles and the heart. In future studies scientists will try to determine what would help protect bones. These studies might include either applying a greater centrifugal force, achieved by spinning faster, or having subjects exercise while they are rotating. If artificial gravity is effective, someday a similar artificial gravity device may be flown in space, or we may even spin the spacecraft very carefully to create gravity inside for the space explorers.



Thea and Diego are participating in a study in which scientists are testing the effects of extra gravity (artificial gravity) on bones and muscles. This is a "human-rated" centrifuge that spins the subjects around while they are lying down. Because they are spinning, there are extra gravity loads on the body. You can feel artificial gravity if you spin around in a circle with your arms out. Your hands will start to feel heavier because you have put additional centrifugal forces on them.

Around the Globe

We have worked with scientists around the world to do space flight studies and ground-based analog studies. We've used bed rest to study bone and muscle loss with colleagues in Boston, Massachusetts; San Diego, California; Galveston, Texas; Toulouse, France; and Cologne, Germany! Can you point out these locations on the map below? We've also worked with scientists from British Columbia, Canada; Hamilton, New Zealand; and Brisbane, Australia!

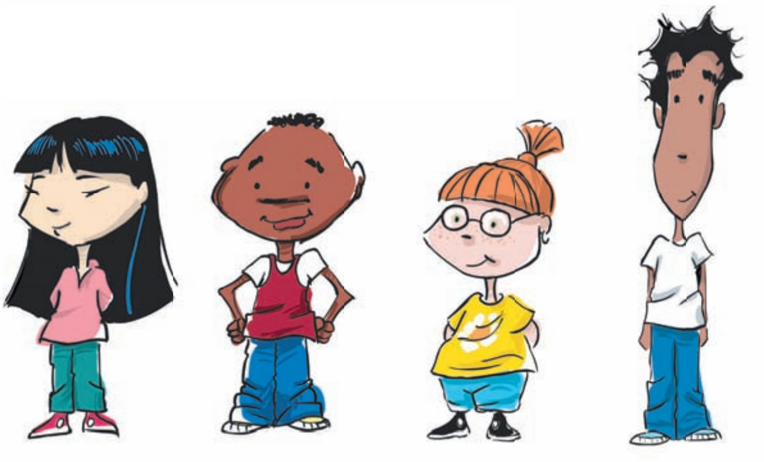
Summary

Doing experiments with all of these space analogs gives us a better understanding of the effects of space flight on the body. The knowledge gained from experiments performed during space flight and in analog conditions will allow astronauts to live and work for the long periods of time that it will take to fly to the moon or even farther—to Mars.

SECTION THREE

Space Flight Nutrition

In this section, Lin, Tim, Thea, and Diego explore the nutritional requirements of space flight.



The Space Nutrition Team will help you discover how important each nutrient is to health here on Earth and in space flight.

What's so important about nutrition?

Eating nutritious food is important to help you grow strong muscles and bones, and to keep you healthy throughout your life. Like it or not, eating is something you really can't live without, and eating right can help determine the quality of your life, whether you are a teen or an astronaut. The main job of NASA's

Nutritional Biochemistry Laboratory is to determine how much of each nutrient (vitamins, minerals, calories) astronauts need to eat while they are in space. Nutritional Biochemistry Laboratory scientists have a set of recommendations for what crew members should eat during space flight, and sometimes they change it because of what their research tells them. They also need to check to see if astronauts in space are getting enough, or too much or too little, of each nutrient.

How do we know if the body is getting the right nutrients? Keeping track of what crew members eat tells part of what we need to know. We do this with a computerized questionnaire, which the astronauts on the International Space Station fill out once a week. Another part of our knowledge comes from collecting blood and urine samples before and after flight, and measuring biochemicals in them that tell us how well the astronauts are processing each nutrient. The concentration of each vitamin and mineral can be determined, and we can measure other biochemicals that tell us about muscle, bone, kidneys, and more! By putting together these two parts of our knowledge, we can look at the relationship between what the astronauts ate and how well their bodies used each nutrient. Then we can estimate whether they are getting enough, too little, or too much of each nutrient.

Lin is completing her Food Frequency Questionnaire. We now know that she likes salmon because she ate it three times this week! Salmon contains a lot of vitamin D and important omega-3 fatty acids that will help protect her muscles and bones during space flight.

As we study more astronauts, we learn a little more about the effects of space flight on the body. Over time, we can learn enough to recommend diets that meet needs for specific nutrients, and the foods can be modified or new foods can be designed so they will provide the right balance of nutrients to the crew. It’s easy to see why nutrition is as important to you as it is to the astronauts!

NUTRIENTS

Our bodies need several categories of nutrients. Macronutrients are ones that we need a lot of, like fat, protein, and carbohydrate. Vitamins and minerals are micronutrients. We don't need a lot of each one, but they are vital for our good health.

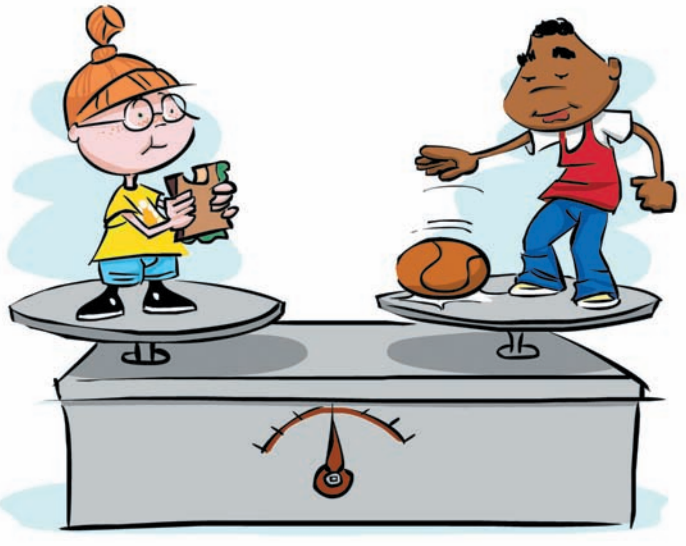
Macronutrients

Fat, protein, and carbohydrate provide the energy we need to grow and do things.

Energy (Calories)

Energy is what keeps us going. Every cell in your body needs energy to function properly. The food you eat provides energy, which is measured in calories. Balancing the energy you take in from foods you eat with the energy your body uses each day is important for good nutrition. Eating enough calories helps make you alert and able to do your schoolwork. Without enough calories, you will be tired and your muscles will not work well. However, too many calories can also be bad for your overall health. Balancing exercise and good nutrition is key to your overall health.

Did you know?
Fat has more than twice as many calories, per unit weight, as carbohydrate and protein.



Thea and Tim know that eating too many calories can lead to gaining weight, and that playing basketball can burn calories that are not burned while sitting on the couch and watching television.

A healthy diet should include the right number of calories. In addition to the total number of calories, the source of calories is important. For a healthy diet, calories should come from the following sources: 50 to 60% from carbohydrate (found in foods like rice, breads, or pasta), 30% from fat (found in foods like whole milk, meat, and nuts), and 10 to 15% from protein (found in foods like whole grains, dairy products, beans, and meat).

Food labels are a great place to learn about your favorite food. First, check the serving size and how many servings are in that package. Next, look at how many calories are in each serving, and what percentage of the calories come from fat, carbohydrate, and protein. For more information about the number of servings of foods you need each day, check out the new guidelines for healthy eating established by the United States Department of Agriculture at http://www.choosemyplate.gov/

Thea and Diego know that maintaining a healthy diet can help them perform better in school, give them energy to play with their friends, and maintain a healthy body.

Vitamins

Vitamin D

Vitamin D is unique in that it can be considered a vitamin or a hormone. A hormone is a biochemical that is made in one part of your body and acts on another part. Vitamin D can be synthesized (made) in your skin when you are exposed to sunlight.

Did you know?
A fortified food is one that has had nutrients added. If you look at a Food Nutrition Label and see vitamins and minerals in the ingredients list, this means they have been added to the recipe.

The Space Nutrition crew is enjoying a quick game of volleyball in the sunshine, and all the time their skin is making vitamin D for strong bones. They also know not to spend more time than 5-10 min in the sun without sunscreen because of the risks for skin cancer.

If you don't get enough sun exposure, you need to get vitamin D from the foods you eat. Vitamin D is found naturally in fish. Milk and cereals (and some orange juices) are fortified with vitamin D. A fortified food is one that has had nutrients added to it. Just read the food nutrition label to find out if the food you eat has any added vitamin D.

Did you know?
Vitamin D deficiency, long thought to be rare, is turning up in kids in America. Be sure to get enough vitamin D in your diet or to get out in the sun for short periods!

Milk and orange juice may be fortified with vitamin D, meaning that vitamin D is added to them. This makes them good dietary sources of vitamin D.

Vitamin D is very important for your bones, in part because vitamin D helps your body use the calcium in your diet. If you don't get enough vitamin D, your body will be "deficient" in that vitamin and won't be able to use calcium from food, and your bones will become weak.

Knowing that vitamin D is synthesized in your skin after exposure to sunlight, you can imagine that getting enough vitamin D from the sun would also depend on the time of year and where you live. Do you think living in Texas or in Alaska would be better for skin production of vitamin D? Often, people who live in places where there is less sunlight have to use artificial light that helps their bodies make vitamin D.

Vitamin D is like many nutrients: although getting too little of it is bad for your health, getting too much can also be bad for you. This usually happens only if you take too many vitamins. Luckily, the body won't get too much vitamin D just from sun exposure. However, too much sun can cause health problems like sunburn, or even skin cancer.

Remember, astronauts are not exposed to the sun during space flight, because the windows of the space vehicle block the specific types of rays that help make vitamin D. The foods on board a spacecraft do not contain enough vitamin D to make up for the lack of sunlight. Even when they are taking extra vitamin D, International Space Station crew members often have a lower amount of vitamin D in their blood after flight than they did before flight.

NASA's Nutritional Biochemistry Laboratory scientists are trying to find the amount of vitamin D that could be used to prevent vitamin D deficiency in astronaut crews. This is very important for astronauts who will be in space for long missions on the ISS or even on the moon, and it is even more critical for missions to Mars. To study vitamin D and the lack of sunlight, we travel literally to the end (or the bottom) of the Earth! The amount of sunshine a person in Antarctica receives during the winter, which is zero, is similar to the amount in space flight. Nutritional Biochemistry Laboratory scientists have performed studies in Antarctica to determine how effective different amounts of supplemental vitamin D would be in space.

Vitamin K

When you get a cut, the blood eventually stops flowing because a blood clot forms. This process is known as “coagulation” (pronounced ko-ag-you-lay-shun). Vitamin K is very important in this process. Vitamin K represents just how exciting the field of nutrition can be. We are still learning more about what vitamin K does in the body, and how important it is for all of us—even astronauts.

Did you know?
Vitamin K is essential for blood clotting. Scientists in Copenhagen, Denmark, discovered this and named the vitamin for its role in “koagulation.”

In addition to its role in blood clotting, vitamin K is very important for bone health. Current research indicates that vitamin K helps bones make proteins that hold calcium in place. Some scientists in Europe (the Netherlands) have investigated whether vitamin K can help protect against bone loss in astronauts.

The story of vitamin K has an unusual cast of characters.

Bacteria...they are a normal part of your digestive tract. Although having bacteria in your intestines may sound gross, it is very important, especially when it comes to vitamin K. The bacteria in your large intestine actually make vitamin K, some of which can be absorbed and used by your body!

Rats....dead ones to be exact…and you thought the bacteria part was gross. What do dead rats have to do with vitamin K? They are a good example of why vitamin K is important. Some types of rat poison are made from a chemical called warfarin that blocks the action of vitamin K in the body. Rat poison works because the rats eat the poison and end up not having enough vitamin K for their blood to clot normally. They die from internal bleeding. This helps show you just how important each vitamin is!

Vitamin K is important for both you and animals including rats! Chemicals such as warfarin that look like vitamin K can actually make vitamin K less available in the body, and as a result blood clotting is less effective. If too much of the drug is given (as is the case with rat poison), the result is that the animal dies because its blood cannot clot properly.

As with most vitamins, the best food sources of vitamin K are vegetables. Vitamin K-rich foods are the dark green and leafy kinds—like spinach, kale, and broccoli. Just a few bites of spinach has all of the vitamin K you need in a day (and a lot of other vitamins as well). Vegetables are an important part of an astronaut's diet, and of yours. You can eat spinach as the green part of your salad, instead of lettuce. Give it a try....it worked for Popeye!

Tim's body will absorb the vitamin K from the spinach he is eating. Other nutrients his body will absorb from spinach are iron, folate, and vitamin A.

Other Vitamins

Every single vitamin is crucial for your body to function. Vitamin K and vitamin D were mentioned above because of their role in bone health, but we also need to be very sure that astronauts get enough of all of the other vitamins. The other vitamins sometimes have complicated names, like thiamin, riboflavin, niacin, vitamins B-6 and B-12, folate, biotin, and pantothenic acid—or they may simply be letters, like vitamins A, C, and E. Vitamins A, D, E, and K are fat-soluble vitamins, meaning they dissolve in your body's stored lipids or fats. The other vitamins mentioned are water-soluble, meaning that they are not stored in your body, and after they are eaten, may be washed out of your body with other bodily fluids. Missing one single vitamin in your diet could be catastrophic to your health.

An example of the havoc wreaked by missing one vitamin is the fact that millions of sailors died in the 18th century from a disease called “scurvy.” Scurvy is caused by missing vitamin C in your diet. After this catastrophe, many ships carried oranges to alleviate the lack of vitamin C in sailors. Today, many foods are fortified with vitamin C, and fresh fruits that supply vitamin C are readily available, but scurvy could still occur if these foods are missing from the diet. We learned an important lesson from those early sailors.

Another example is a disease called “pellagra.” Thousands of deaths occurred from this disease in the early 1900s before doctors figured out that it was caused by a lack of niacin in the diet. Now, niacin is added to many foods you purchase in the grocery store. Read the food nutrition label on foods such as cereal and instant oatmeal to find out if you are buying foods with niacin added.

Even though we know about these diseases now and which vitamins we need to include in the space food system, we need to make sure that the vitamins remain stable and will still be in the food by the end of a 3- to 5-year trip to Mars. Stability studies done during space flight and on Earth have provided (and will continue to provide) valuable data to determine the shelf life of nutrients in the food system.

Minerals

Calcium (and Bones!)

Did you know?
People with osteoporosis have extremely weak bones that can be very painful. They have to be careful because they could break a bone just by falling down.

Calcium (kal-see-um) is a mineral our bones need to grow and be strong. Calcium is found in many of the foods and beverages we eat and drink. Did you know that milk, broccoli with cheese, and pizza are loaded with calcium? If we don't eat enough calcium, our bones become weak. Healthy bones have millions of tiny holes in them that are part of the bones' framework or structure that helps make them strong and keep our bodies standing up. The part of the bone that has these holes is called "cortical bone." Without calcium, the tiny holes start to become larger. This can cause the bone to become very brittle, and can lead to a disease called "osteoporosis" (os-tee-oh-por-oh-sis). Although osteoporosis usually occurs in older people, not getting enough calcium can be bad for anyone! Calcium is needed for other things besides bones. We need calcium for strong muscles, healthy blood, and healthy teeth and gums. How much calcium do we need? People 9 to 13 years old need to eat 1,300 milligrams (mg) of calcium each day. For young people 9 to 13 years old, your percent daily value (% DV) numbers for all the foods you eat in a day should add up to at least 130% DV for calcium each day.

Reduced gravity (microgravity) in space produces less pressure on your bones because you are not using them to hold your body up against the gravitational force of Earth. This causes them to not be as strong as they are on Earth. Astronauts lose bone during space flight. Simply eating more calcium is not going to help their bone loss because their body's ability to absorb calcium is decreased during space flight.

Did you know?
A milligram (mil-li-gram) is a measurement of the amount of a mineral in the food you eat. If you look for calcium on a food nutrition label you will not see it listed in milligrams. Instead, you will see it listed as the percent of daily value (% DV). The % DV listed on a food label is the one for adults. For young people 9-13 years old, your % DV numbers for all the foods you eat in a day should add up to at least 130% DV each day for calcium.

Did you know?
Almost 99% of the calcium in our bodies is found in our bones.

Vitamin D helps the body absorb calcium from the diet.

Women have to really watch their calcium intake because they are more likely to develop osteoporosis than men.

Tim may need to include more foods with calcium in his diet. What else can he do to develop strong bones? One way astronauts keep strong bones during space flight is to do "resistive" exercise, such as using a muscle or a machine or device to resist the force of another muscle. Participating in activities like playing hopscotch and jumping rope can help make your bones strong.

Scientists are researching ways to provide astronauts with the right amount of calcium that will keep their bodies healthy when we send them on exploration missions.

Iron (and Blood!)

Iron is a very important mineral that has many functions in your body. Iron works with proteins in the body to produce energy from fat and carbohydrate in your diet. In fact, if you don't eat enough iron, you will get tired more easily and you may not be as alert during school.

Can you tell the difference between Lin and Diego? Which student had iron-fortified cereal for breakfast? What types of foods do you eat that contain iron? Iron is found in meat, eggs, dried fruits, pumpkin, fish, and iron-fortified cereals. If you read the food nutrition label, you will find the iron content of the foods you are eating.

Iron is also important for transporting oxygen in blood to all of your tissues and organs. Iron is stored in erythrocytes (uh-rith-row-sites), the red blood cells. About two-thirds of the iron in the body is stored in erythrocytes. The rest circulates through the blood bound to another protein, called transferrin, and some iron is stored in tissues. Many proteins in cells use iron for important cellular processes.

Erythrocytes act like a delivery truck full of oxygen that delivers oxygen to the areas in the body that need it. Iron deficiency can happen because of a lack of iron in the diet, or excessive bleeding. The disease that is the result of a severe iron deficiency is called anemia.

Where are these oxygen molecules headed? What does the truck represent? What mineral helps get oxygen to the areas in your body that need it?

Iron-deficiency anemia impairs brain development in infants and kids. Although iron deficiency can be reversed by adding more iron to the diet, scientists are not sure whether the effects on the brain can be reversed. So... it's important to include iron-rich foods in your diet, such as meat, eggs, dried fruits, pumpkin, and fish.

Did you know?
The iron in red blood cells is what gives blood its red color.

Vitamin C increases your body's ability to absorb iron from the diet. So…next time you eat some oatmeal or cereal, put some strawberry slices on top to increase your absorption of iron!

Space flight has many effects on the body, and the iron and blood changes are some of the most unique. Astronauts have fewer blood cells during space flight, but this does not seem to be related to not getting enough iron in their diets. In fact, we are concerned that astronauts might get too much iron during space flight. This is the opposite of concerns for people on Earth, where too often people don't get enough iron in their diets. This is very important, especially for growing kids.

Tim is pumping iron. Is this the same kind of iron that is found in the foods you eat to maintain your good health?

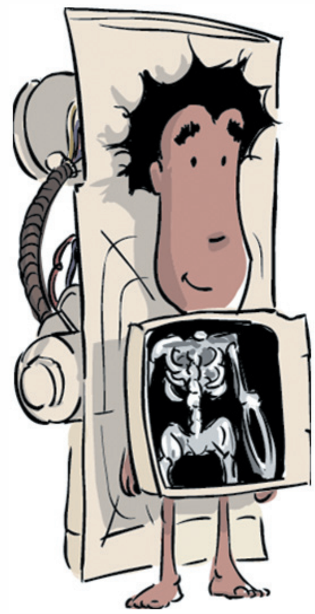
Radiation

Did you know?
Just as length is measured in a unit called a meter, radiation is measured in a unit called a rem. One-thousandth of a rem is called a millirem (similar to how one-thousandth of a meter is called a millimeter).

Most Americans are exposed to about 360 millirem of radiation per year. Check out http://www.epa.gov/radtown/enter-radtown.html *to learn about your exposure to radiation.*

UV radiation from the sun can be beneficial, as when sunlight makes plants grow, or harmful, as when overexposure to the sun's rays causes sunburn.

Everything around us is made up of very small particles called atoms, which are constantly moving. The atoms in an object can be packed very close together or be relatively far away from each other. This packing determines which state the "matter" of an object is in—solid, liquid, or gas. Solids have atoms that are very close together; an example is a rock. Liquids have atoms that are also close together, so they are also hard to compress. Gases have atoms that move freely, and in fact the atoms try to spread themselves out. Some atoms in solids, liquids, or gases aren't as "calm" as others. These "nervous" atoms are unstable, and when moving around, they give off energy. We call this energy "radiation." As they move, the atoms try to become calm again, or become stable.



Sometimes, in a visit to the doctor or hospital, we may find that we need to have an x-ray. This helps the doctor to look inside our body and help heal what might be wrong.

Believe it or not, we are surrounded by radiation all the time. Radiation comes from outer space, the sun, the Earth, and even from our own bodies! Radiation can also come from cellular phones, televisions, microwaves, glow-in-the-dark watches, high-voltage power lines (these are lines that distribute electricity to your home), and many other items. Radiation can be very helpful to us—it can be used to fuel power plants, to produce medical x-rays, or to treat cancer.

Too much radiation exposure can be bad for our health and for the environment. The radiation given off by the sun can be quite dangerous to humans on Earth when they are exposed to too much sun. In space, the astronauts are outside the protection of the Earth's atmosphere, so they are exposed to more radiation than we are here on Earth. Astronauts wear spacesuits that protect them from many dangers in space, one being radiation. During space walks, astronauts must wear face shields in their helmets to protect themselves from the large amount of ultraviolet (UV) radiation. UV radiation can cause damage to the skin, commonly known as sunburn. On Earth, the ozone layer and lower atmosphere help to protect us from some of the UV radiation given off by the sun. Some of the UV light filters through the atmosphere and still reaches us here on Earth, which is why we protect ourselves with sunglasses and sunscreen with sun protection factor (SPF) 15 or higher.

Energy produced by the sun has many different wavelengths, and only a few of them are visible. Ultraviolet light cannot be seen by humans, but it can damage your skin. Prolonged exposure can wrinkle skin after many years, or skin cancer may form.

SPF (sun protection factor) is a number on a scale of 2-100, and describes a product's ability to block out the sun's burning rays.

Oxygen Damage (Oxidation)

Have you ever wondered why an apple turns brown after being cut? The brown color is caused by a process called oxidation (ox-ih-day-shun). Oxidation happens when oxygen molecules react with other molecules such as protein or fat, and damage their structure. Just as apples can be damaged, our bodies can also be damaged by oxidation. Why is oxidation a bad thing? The process of oxidation produces molecules called free radicals that can damage cells in our body. A free radical acts sort of like a thief. It is a molecule that is missing an electron, and therefore steals electrons from healthy (normal) molecules. Years of exposure to free radicals may cause serious health problems, such as cancer or heart disease.

The Space Nutrition Newsletter team members want to stop the free- radical thief from taking their body's vitamin E. Eating a diet rich in antioxidants, such as foods containing vitamin C, is a good way to stop free radicals from forming.

Did you know?
The number of food components that act as antioxidants is greater than 4000.

A good source of the antioxidants called polyphenols is dark chocolate.

Space flight exposes astronauts to oxidation from the sun's radiation and from high concentrations of oxygen in the atmosphere of the spacecraft and the EVA suit.

Oxidation in our bodies can be caused by environmental factors such as exposure to air pollution and cigarette smoke, and overexposure to sunlight.

How do we stop oxidation? Antioxidants are substances that slow or stop oxidation in our bodies. If you sprinkle a cut apple with orange juice, then it will not turn brown. This is due to the fact that orange juice and all citrus fruits are a great source of antioxidants, such as vitamin C. Natural foods with a lot of color are usually good sources of antioxidants. Here are a few that can be found in the diet: beta-carotene (mangos, carrots), zinc (milk, nuts, shellfish), vitamin C (oranges, strawberries), flavonoids (green tea, apples), vitamin E (avocados, nuts, seeds), and selenium (seafood, lean meats).

The foods you eat at every meal should include antioxidants. Look at what you are eating. Do the colors of your foods look like a rainbow? A variety of colors at every meal are a good indication that you are getting enough antioxidants.

Summary

Many nutrients are required by our bodies. Some provide energy, like protein, carbohydrate, and fat. Others, like vitamins and minerals, carry out important activities to help in almost every aspect of your body's daily chores. Knowing some of these details might help you understand why a balanced diet is critical, to make sure you have all of the nutrients you need to keep you healthy. Too little, or often too much, of any single nutrient can cause health problems. Balance is the key!

SECTION FOUR

Being Healthy is Not Just About Nutrition (Even Though We Like to Think it is)

The Nutritional Biochemistry Lab is part of a larger group of research laboratories working to understand the changes in the human body as it gets used to weightlessness.

Exercise Lab

Exercise affects almost all systems of the human body, in people on Earth as well as in astronauts during space flight. Exercise is one of the most common means of trying to counteract, or reverse, the negative effects of space flight on the heart, blood vessels, muscle, and bone. The Exercise Physiology Laboratory at the Johnson Space Center is a team of scientists and engineers who are trying to understand the effects of microgravity (weightlessness) on human performance (or fitness), and to develop exercises to help keep astronauts healthy during and after their missions. The Exercise Team at NASA builds exercise equipment that will work without gravity, and does tests to be sure that the exercises that crew members do in reduced-gravity environments will help keep them healthy.

Lin is riding her bicycle. She rides it at least 3 times a week to make sure her bones, muscles, and heart remain healthy. What exercises do you do each week to stay healthy? Do you have physical education class in school? What else can you do to keep your body healthy?

Exercise and nutrition are important components of a healthy lifestyle, whether you live on the ISS or here on Earth. Developing good eating and exercise habits when you are young will help you keep healthy as you get older.

What you do when you are 10 to 20 years old can have big effects on how healthy (or sick) you are when you get older. Bone is a great example of this. If you eat and exercise right through your teen (and pre-teen) years, you'll be less likely to get osteoporosis when you are older. Osteoporosis is a disease that makes the bones get very weak and brittle, and break easily. It is usually thought of as a disease of the elderly, but prevention of this disease is best started in the first 10 to 15 years of your life!

Different types of exercises can help different parts of the body. Aerobic exercises, like running on a treadmill or riding on a bicycle, can help to keep your muscles from losing strength and help to keep changes from occurring in your heart and your blood circulation. Weight lifting, a form of what is called "resistive exercise," can also help to keep you from losing bone strength.

Cardiovascular Lab

The circulatory or cardiovascular system is made up of the heart, blood vessels, and blood. The blood vessels that carry blood away from the heart are called arteries, and those carrying blood to the heart are called veins.

Many changes occur in the cardiovascular system during space flight. The heart does not have to work against Earth's gravity to supply blood and oxygen to the body. Not having to work so hard can weaken the heart muscle and can reduce its ability to provide blood and oxygen to the brain when the astronauts return to Earth. This can cause light-headedness and reduce the astronauts' ability to walk or exercise. The Cardiovascular Laboratory at the Johnson Space Center is a team of scientists and engineers who are trying to understand the changes in the cardiovascular system that are caused by microgravity and find ways to improve the astronauts' ability to adapt to these changes, both during and after space flight.

Neurosciences Lab

Tim is dizzy from spinning around and then standing up. This is the same type of effect that reduced gravity has on the neurovestibular system. Tim is dizzy because the fluid in his ears has been affected by his movement as he travels in circles.

Have you ever spun yourself around to make yourself dizzy? The nervous system (nerves, brain, eyes, and inner ear) is affected when you spin around. This system is also affected by lack of gravity. The Neurosciences Laboratory at the Johnson Space Center investigates the effects of space flight on the nervous system. "Neuro" comes from "neuron," the Greek word for nerve. "Neuron" is also an English word for nerve cell. The nervous system controls all actions of the muscles, including those that result in movements of the eyes, head, and body. Scientists and engineers in the Neurosciences Laboratory measure changes in what the eyes see, what the brain tells the muscles to do, and how the muscles respond to this information before and after space flight.

The Neurosciences Laboratory also studies the effects of space flight on the neurovestibular system (NVS), the nerves and organs that keep the body in its proper orientation. The inner ear is a very important part of the NVS. Organs in the inner ear help us to keep our balance by telling the brain about the motion and position of the body. Without gravity, the NVS needs to readapt, and the brain has a hard time figuring out which way is up. Scientists and engineers work together to develop training programs to help the NVS so that astronauts can stay in space longer.

Behavior and Performance Lab

Do you think you could share your classroom with 2 of your closest friends for 6 months, 24 hours a day, away from everyone else you know? Would you be homesick? Would you worry about your family? Would you get tired of working in the same room with your friends every day? The members of the Behavior and Performance Lab try to understand what the astronauts will experience emotionally while they are in space. They work with other medical team members to determine the stresses involved with each mission into space, such as differences between crew members, the isolation of being in space, and the work required of the crew during their mission. Scientists develop techniques that help astronauts deal with the stress of being away from home and working with the same people every day (all day) for weeks to months at a time. Some of the techniques that astronauts are encouraged to use are making phone and video calls to family members, and participating in a hobby during the flight (activities like playing the guitar, reading books, or watching movies). Exercise is another great way to help reduce stress, and it helps your muscles too!

The Next Frontier—Exploration

The Shuttle and International Space Station fly in what we call “low Earth orbit,” meaning that they are about 100 to 150 miles from the Earth’s surface. In the big picture, there’s a lot more out there to explore. The moon was our first stop, and that was about a 3-day trip. NASA is starting to look outward even farther, and is contemplating someday going off to check out an asteroid, and then perhaps going on to Mars. Given the technology we have today, and the nature of travel to other planets, a trip to Mars is expected to take about 6 months for travel to get there, about 18 months for a stay on the planet surface, and then about another 6 months to get back. In total, this is about 30 months, or 2½ years. This is a much bigger challenge than our current missions (which were by no means “easy”). Imagine how much food you would eat in 2½ years, or how much water you would drink. These are just two of the issues that we in nutrition think about now. Future exploration will require planners to consider even more—everything from clothes to oxygen to exercise will have to be very carefully planned. There’s no store or restaurant along the way where you can pick up anything you forget. These will be difficult missions, but they represent the next major leap in human exploration.

Our Space Nutrition Team—Lin, Tim, Thea, and Diego—have enjoyed sharing their space adventures and look forward to learning about the challenges and exciting opportunities that future space exploration will bring.

Glossary

adaptation – the process of adjusting to the environment or to specific conditions (in space flight, adaptation is the process of adjusting to the lack of gravity and being in a closed environment).

airlock – an air-tight chamber or room that allows passage to or from the vacuum of space. On the International Space Station, the airlock module is named “Quest.”

Apollo – in ancient Greek mythology, the name of a god. In space flight the Apollo missions were a series of manned and unmanned space flights to and from the moon.

aquanaut – an underwater explorer. In the U.S. space program, aquanauts are the research subjects participating in studies in an underwater habitat.

astronaut – a space explorer. In space flight this is the name given to U.S. space explorers; the Russian counterparts of astronauts are called cosmonauts.

bed rest – a type of study often used to simulate weightlessness and evaluate effects on the body.

biochemistry – the chemistry of living matter.

blood serum – the clear yellow liquid that can be separated from blood cells when whole blood clots. Blood serum is tested to understand what is happening to the human body before, during, and after space flight.

coagulation – formation of a blood clot.

Columbia – poetic name for the USA. In the U.S. space program Columbia was the first Space Shuttle orbiter to orbit and return to Earth. On February 1, 2003, the Space Shuttle Columbia disintegrated over Texas during its return to the Earth’s atmosphere, resulting in the death of all seven crew members.

convection oven – an oven equipped with a circulating fan that intensifies the amount of heat in the oven and decreases the normal cooking time. In space flight a convection oven is used to reheat food in the kitchen area of the spacecraft.

cosmonaut – a space explorer in the Russian space program. (Space explorers from the U.S. and other nations are called astronauts.)

deficit – a lack or shortage.

docking or docked – attaching or attached to a site such as a pier. In space flight this is the joining of one space vehicle with another or with a space station in space.

EVA – extravehicular activity. In space flight, this is the term for space walks. EVAs are used to repair or construct parts of the space vehicle.

Gemini – in astronomy, a constellation (the Twins); it is used in astrology for people born between May 21 and June 20. In space flight, Gemini was a U.S. program in the 1960s, in which two-person space vehicles were flown to prepare for the Apollo moon landings.

habitat – a place or environment where people (or other creatures) can live.

International Space Station – a giant environment for living and working that orbits the Earth once every 90 minutes. The ISS was built in sections called "modules" that were taken to space either in the Space Shuttles or on Russian launch vehicles.

medical monitoring – the measurement of physiological data before, during, and after space flight to ensure optimal astronaut health.

Mercury – the United States' first space program in which humans were sent to space. Mercury astronauts were launched into space on either a Redstone or Atlas rocket, depending on how far they traveled.

MERLIN – the Microgravity Experiment Research Locker/Incubator, a small refrigerator/freezer for the ISS.

mid-deck – one of the 2 levels (flight deck and mid-deck) of the crew compartment on the Space Shuttle orbiter. The mid-deck is "downstairs," and is where most experiments are conducted, where the "kitchen" is, and where the bathroom is.

Mir – the first Russian space station.

Mission Control Center – the center that controls activities of space flight, or dive activities for the NEEMO program.

muscle atrophy – a process by which muscles weaken during space flight.

NEEMO – NASA Extreme Environment Mission Operations. These missions are conducted in an underwater habitat off the coast of Florida on the bottom of the ocean (about 50 feet below the surface)

neuroscience – the science of studying the nervous system. The Neuroscience Laboratory at NASA's Johnson Space Center studies changes in what the eyes see, what the brain tells the muscles to do, and how the muscles respond to this information before and after space flight.

Neutral Buoyancy Laboratory – a giant swimming pool for diving that allows astronauts to train for space missions involving space walks.

nutritional biochemistry – the study of how nutrients in food affect how our bodies work. Every cell in your body requires many different vitamins and minerals as well as energy to keep you alive and healthy.

nutrients – energy (carbohydrates, fats, proteins), vitamins, and minerals that are needed for growth and development and that are required from the environment.

NVS – the neurovestibular system, which includes the nerves and organs that keep the body in its proper orientation. The inner ear is a very important part of the NVS.

orbit – the path an object takes around another object. The Shuttle and International Space Station orbit the Earth, and they do this once every 90 minutes.

orbiter – a vehicle that can travel around the Earth. There are some sub-orbital vehicles that can provide seconds to minutes of weightlessness, but they do not travel around the Earth. Six Space Shuttle orbiters were built: Enterprise (never flown in space, was used for testing landings), Columbia, Challenger, Discovery, Atlantis, and Endeavour.

osteoporosis – a disease that makes the bones get very weak and brittle, and break easily.

planetary travel – travel between planets, such as Earth and Mars.

Progress cargo vehicle – an unmanned Russian resupply vehicle that delivers supplies or food to the ISS. There are 3-4 Progress flights per year. It does not return to Earth – instead, it is packed with waste and used goods from the ISS and burns up upon reentry into the Earth's atmosphere.

rehydratable – a food that is dehydrated, meaning all of the water has been taken out. Water can be added back to the food to rehydrate it before it is consumed.

solar – relating to the sun.

shelf-stable – refers to a food item that is not likely to spoil for at least 6 to 12 months.

Space Shuttle – a NASA reusable launch vehicle that included an orbiter capable of orbital flights. The first Shuttle launched in 1981 and the last Shuttle mission flew in 2011.

space flight – travel though outer space.

space walk – NASA calls space walks "extravehicular activity" (EVA). It is a very important part of many space missions. When astronauts need to go outside the Space Shuttle or International Space Station, they have to put on a special suit that acts like a personal spacecraft. The EVA suit provides pure oxygen for the astronauts to breathe, and is cooled with a special suit underneath that can have cool water circulating throughout it. During an EVA, astronauts can be in these suits for up to 10 hours.

SPF – sun protection factor. The SPF number is listed on sunscreen containers to let you know how much ultraviolet radiation can reach your skin. The higher the number, the more protection the sunscreen provides.

Stability – a study conducted by the Nutritional Biochemistry Laboratory to determine the effects of long-duration space flight on nutrients in space foods. Foods can become stale, or sometimes taste funny (or bad) when they are too old, and this taste is often caused by vitamins and other nutrients breaking down into other chemicals over time. If enough of a nutrient breaks down, then the food is no longer providing the nutrients we expected it to provide.

thermostabilized – heated to very high temperatures to destroy bacteria and then packaged in cans or closed pouches. Examples of thermostabilized foods are canned ravioli and soups.

ultraviolet (UV) radiation – a type of radiation from the sun that can cause damage to the skin, commonly known as sunburn. On Earth, the ozone layer and lower atmosphere help to protect us from some of the UV radiation given off by the sun. Some of the UV light filters through the atmosphere and still reaches us here on Earth, which is why we protect ourselves with sunglasses and sunscreen with sun protection factor (SPF) 15 or higher.

National Science Education Standards

Science Content Standards K - 12

Unifying Concepts and Processes - As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, chance, and measurement
- Evolution and equilibrium
- Form and function

Content Standard A - Science as Inquiry:
Grades 5-8:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B - Physical Science:
Grades 5-8:

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Content Standard C - Life Science:
Grades 5-8:

- Structure and function in living systems
- Reproduction and heredity
- Regulation and behavior
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D - Earth and Space Science:
Grades 5-8

- Structure of the Earth system
- Earth's history
- Earth in the solar system

Content Standard E - Science and Technology:
Grades 5-8

- Abilities of technological design
- Understandings about science and technology

Content Standard F - Science in Personal and Social Perspectives:
Grades 5-8

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Content Standard G - History and Nature of Science:
Grades 5-8

- Science as a human endeavor
- Nature of science
- History of science

Adapted from National Science Education Standards, copyright 1996 by the National Academy of Sciences.

Some strategies for teaching and learning using *Space Nutrition* in the rest of the book are listed below. Some strategies are used before reading to prime students and get them ready to learn; other strategies are useful in processing the information given to the reader. Lastly, some strategies help students hold on to the learning by reflecting and retaining the information.[1]

GETTING READY TO LEARN: PRIMING

A Taxonomy of Words for Space Nutrition: Rothstein, E. & Lauber, G. E. (2007). *Writing As Learning*. Second Edition. Thousand Oaks, CA: Corwin Press.

- Begin by folding a sheet of notebook paper into two columns by using a "hot dog"-style fold.
- Use the letters A-M and N-Z to identify each category for your words, skipping lines between letters.
- Build your Taxonomy of Words for Space Nutrition by adding new words to the list before, during, and after reading, using each letter of the alphabet as a category heading.
- Display the words on a classroom Taxonomy of Words for Space Nutrition drawn on large chart paper.
- Use the words for quick reference when writing about, discussing, or working with *The Space Nutrition Newsletter: The Book.*

Anticipation Guide: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12.* Second Edition. Thousand Oaks, CA: Corwin Press.

- Create a set of questions from a portion of *The Space Nutrition Newsletter*: The Book on specific points you want to emphasize.
- Make sure the questions can be either agreed or disagreed with by the learners.
- Make no more than 5 questions.
- Present the questions to the class. Ask them to quietly agree or disagree with the questions.

[1] *From the National Urban Alliance for Effective Education Pedagogical Flow Map. Copyright NUA, 2009, all rights reserved.*

- Ask tables of students to discuss their answers, using facts to defend their choices.

- Read the selected portion of the text.
- Again, present the questions to the class. Ask them to quietly rethink their former decision.
- Ask tables of students to discuss their answers and defend their choices. If they have changed their answers, ask them to explain why

Key Word Prediction: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12.* Second Edition. Thousand Oaks, CA: Corwin Press.

- Choose a topic from *The Space Nutrition Newsletter: The Book.*
- Choose 8-15 words from the Glossary that pertain to the chosen topic.
- Display the words and the topic for the students to view.
- Have students predict the relationship of the words to the topic.
- Have students read the designated portion of *The Space Nutrition Newsletter: The Book.*
- Students then discuss the relationship of the words to the topic, according to what they have read.
- Were their predictions correct?

List, Group, Label: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12.* Second Edition. Thousand Oaks, CA: Corwin Press.

- Choose a specific set of vocabulary words from *The Space Nutrition Newsletter: The Book.*
- Have tables of students group the vocabulary words, using whatever method they choose.
- Extend the activity by having students label the groups of words.
- Have groups of students discuss why they chose each label.

UNPACKING THE MEANING: PROCESSING

Key Word Notes: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12.* Second Edition. Thousand Oaks, CA: Corwin Press.

- Chunk a portion of text from the Space Nutrition Book into 4 sections. Each section should be able to be completely read in about 2 minutes.
- Each student should design a layout for Key Word Notes on their paper as follows:

Key Word Notes for ___(topic here)________

1	2
3	4
Summary:	

- Have each student read the chunked text labeled section one, and take notes from their reading in box 1 of the Key Word Notes, using 3-5 words that resonate with them from the text.
- After a specified time limit, have the students stop and discuss what they read with other students at their table, using the notes from box 1.
- Begin reading again with section two, taking notes in the box labeled 2 and stopping after a specified time to discuss your notes with your table.
- Continue on to sections 3 and 4.
- After the text is read, put it away.
- Without looking at the text, have students summarize their reading in the summary box on the Key Word Notes.
- Have students share their summaries with their table.
- Display the Key Word Notes pages for the class to read and share.

HOLDING ONTO THE LEARNING: RETAINING FOR MASTERY

Assessing student knowledge acquisition using strategies other than formal testing:

- Flow Map: *from David Hyerle's "Thinking Maps," 2007, Thinking Maps, Inc.*
- Using sequencing, formulate a flow map to show the progression of human space flight.
- Design a flow map to show the steps of the scientific method. Where would you place each of the steps of the experiments provided in *The Space Nutrition Newsletter: The Book* on the flow map?
- Again, a taxonomy of words can be used as an assessment of learning, and so can words that have been internalized during discussion.
- Squared Away[2]: What are you squared away on? What is still rolling around in your head? What will you make a point of doing?
- Develop projects from this publication. Have the students conduct a Gallery Walk and give affirmations.
- Devise studies based on the scientific method, such as the lemonade study. Have student groups display the study they developed.

- Develop a radio show based on nutrition and space. Deliver it to your school in the morning anouncements each morning. Written scripts can be displayed.

[2] *From the National Urban Alliance for Effective Education. Copyright NUA, 2009, all rights reserved.*

- Conduct lessons for children in previous grades on nutrition, space, and how nutrition affects their performance in school. Display the lesson plans.
- Put on a play for your school that includes skits, songs, and dances based on the book. Let groups choose topics based on their interests and strengths. Display the scripts, along with pictures from the dramatization.

Some questions for reflection: *from Dr. Yvette Jackson's "The Pedagogy of Confidence: Inspiring High Intellectual Performance in Urban Schools," March 2011, Teacher's College Press.*

- What else does this remind you of?
- Where else have you heard this information?
- Where else might you use this information?
- How can you apply this space research to your life?
- What type of pattern do you see between food intake and exercise, and physical health?
- How would you feel about what you read if you were an astronaut?

Some ways to use this book:

- Good health and nutrition studies
- Exercise precursor
- Interdisciplinary studies in health, physical education, and science standards

Extra activities:

- Make an antioxidant fruit salad: http://www.nasa.gov/centers/johnson/slsd/about/divisions/hacd/education/kz_facts.html
- Understanding the science behind radiation levels: http://www.epa.gov/radtown/enter-radtown.html
- Food planning and ideas for nutrition for specific audiences: http://www.choosemyplate.gov/

For more information on education and NASA please visit www.nasa.gov

About the Authors

Scott M. Smith

Dr. Smith has been a member of the NASA Nutritional Biochemistry Laboratory team since 1992. The primary goal of this group is to determine the nutritional requirements for extended-duration space flight. This involves conducting both operational and research activities. Operational activities include the assessment of nutritional status of crew members on missions to the International Space Station. Dr. Smith has been the principal investigator for experiments on International Space Station missions, Space Shuttle missions, and joint U.S./Russian missions to the Mir Space Station. He has also led many ground-based research projects, including studies of vitamin D supplementation in the Antarctic and extended-duration bed rest studies. He is co-author of dozens of scientific publications, including the book *Nutritional Biochemistry of Space Flight*, available via open access at: https://www.novapublishers.com/catalog/product_info.php?products_id=20061

Dr. Smith participated in the definition of the current nutritional recommendations for extended-duration space flight, and is Co-Chair of the Multilateral Medical Operations Panel - Nutrition Working Group, which includes representatives of the 5 ISS partner space agencies: Canada, Europe, Japan, Russia, and the U.S. Dr. Smith has served on the Editorial Board of the *Journal of Nutrition.* He is a member of the American Society for Nutrition, the American Physiological Society, and the International Academy of Astronautics.

Dr. Smith received a B.S. in biology and a Ph.D. in nutrition, both from Pennsylvania State University. After completing a postdoctoral fellowship in North Dakota, he moved to Houston in 1992 to work at the Johnson Space Center.

Janis Davis-Street

Dr. Davis-Street is the Associate Manager of Health and Productivity in Chevron's Corporate Health and Medical department. The Health and Productivity group provides targeted interventions for identified health risks and designs health education and health promotion programming for employees, with a focus on prevention of injury and disease. Key focus areas include a global cardiovascular health program, onsite fitness centers, and prevention of office-based repetitive stress injuries.

Dr. Davis-Street has served as a member of the National Business Group on Health's (NBGOH) Racial/Ethnic Health Disparities Advisory Board and is a current member of NBGOH's Global Health Benefits Institute. She obtained her M.S. in nutrition from the University of Alberta and her Ed.D. in health education from the University of Houston. Before working at Chevron, she spent 15+ years as a nutritionist at the Johnson Space Center, where for much of her tenure she partnered with Dr. Smith and others to support K-12 education outreach efforts. At JSC, Dr. Davis-Street was involved in nutrition research on International Space Station missions, Space Shuttle missions, and joint U.S./Russian missions to the Mir Space Station. She also participated in the experiment design and evaluation of several ground-based research projects, including extended-duration bed rest studies and exercise countermeasure protocols.

Dr. Davis-Street is a Certified Health Educator Specialist whose interests include corporate wellness, health and productivity, health disparities, and the roles of nutrition and exercise in preventing chronic diseases such as osteoporosis, cardiovascular disease, diabetes, cancer, and obesity. She has co-authored more than 20 peer-reviewed scientific papers in the areas of nutrition and space flight.

Lisa Neasbitt

Ms. Neasbitt is a Science Consultant for AUSSIE Professional Development in Manhattan, New York; a Mentor for the National Urban Alliance in Syosset, New York, and a Data Consultant for the College Summit working with the Bill and Melinda Gates Foundation to encourage a college-bound culture for seniors in high schools across the nation.

Supporting NASA education, Ms. Neasbitt designed elementary and middle-school science, technology, engineering, and mathematics educational materials concerning the U.S. Vision for Space Exploration. Before she joined the NASA education team, Ms. Neasbitt's work experience included science and technology facilitation in public schools; internal facilitation for Federal Teaching and Learning Grant recipients; curriculum correlation for textbook publishers;

and curriculum development, publication, and instruction for the Michael Dell Children's Museum. Ms. Neasbitt has been the recipient of many local, regional, state, and national science education distinctions. She was nominated by her students for Educator Astronaut, and was an Educator Astronaut applicant.

Having science curriculum and instruction experience totaling over 20 years, Ms. Neasbitt holds a B.S. from Texas A&M University, and has conducted graduate studies at the University of Houston, the University of Houston - Clear Lake, and Texas A&M University. She holds a lifetime Texas teaching certification in elementary and science education. A member of the Association for Supervisory and Curriculum Development, the National Science Teachers Association, and the National Association for Bilingual Educators, she has presented educational materials published with NASA in over 75 workshops nationally and internationally.

Ms. Neasbitt served on Houston Mayor Bill White's Wellness Council, representing the NASA Johnson Space Center Human Research Program Education and Outreach Project. She initiated and sustained NASA partnerships with the Houston Independent School District and major-league sports teams including the Houston Dynamo, the LA Galaxy, and the DC United, as well as government agencies including the Food and Drug Administration, Health and Human Services including The Surgeon General, The President's Council on Physical Fitness and Sports, and the United States Department of Agriculture.

Sara R. Zwart

As a member of the Nutritional Biochemistry Laboratory at the Johnson Space Center, Dr. Zwart has been involved with research investigating relationships between nutrition and physiological effects of space flight, including bone and muscle loss, changes in iron metabolism, and oxidative damage. The Nutritional Biochemistry Laboratory is charged with defining the nutritional requirements for extended-duration space flight. Operational and research activities are being conducted to define the impact of space flight on human physiology and nutritional requirements.

Space flight studies include nutritional assessments during long-duration space flight and modification of the diet to help prevent bone loss associated with space flight. Ground-based research is used to understand the role of nutrition in ground-analog studies that simulate varied aspects of space travel. These include rotating cell culture models, NASA Extreme Environment Mission Operations (NEEMO) undersea missions, extravehicular activity analogs at the Neutral Buoyancy Laboratory at the Johnson Space Center, bed rest, and Antarctic winter.

Dr. Zwart earned her Bachelor of Science degree in biological sciences from the University of Notre Dame in 1999, and her doctorate in nutritional sciences from the University of Florida in 2003. She joined the Nutritional Biochemistry Laboratory at NASA's Johnson Space Center in 2003 as a National Research Council Post-doctoral Fellow, and then began as Research Scientist in the laboratory in 2005. She is now Senior Scientist and Deputy Manager for Nutritional Biochemistry.

About the Illustrator

Marco Zambetti

Currently a Creative Director at Tietronix Software, Inc., an information technology company, Marco Zambetti is involved in the art production for serious games and interactive applications, as well as promotional and informational material.

Originally from Italy, in 1979 Mr. Zambetti moved to the United States where, after a period of doing odd jobs as an illustrator and portrait artist, he landed a position as a graphic designer at a large computer manufacturer. There, from the summer of 1984 to the fall of 1988, he produced numerous computer-generated graphics and animated videos. In 1988 he accepted a position as a staff artist/animator at NASA's Johnson Space Center, where he produced videos aimed at informing and educating the public on the activities and goals of the space program.

Mr. Zambetti attended the University of Milan department of physics (1974-1975), the Los Angeles Trade Technical College commercial art department (1982-1984), Boston University department of computer science (1985-1986), and the University of Houston - Clear Lake (2006-2011). He has a Bachelor of Arts in applied visual arts and a Master of Science in mathematics.

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